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ABSTRACT

Prepared for a 1984 Organisation for Economic Cooperation and Development (OECD) conference, this report on the educational applications of new information technologies focuses primarily on the use of interactive audiovisual systems. Potential advantages of interactive multimedia educational environments are discussed and examples are given of educational packages soon to be available that involve simulation and the application of artificial intelligence. A review of the courseware design process phases and definitions of terms used to describe courseware structure are followed by an outline of the principal hardware elements of future computer assisted instruction systems and cost trends. Capabilities of the software, which controls courseware question and answer sequences and their presentation via the audiovisual environment, are discussed, and the computer assisted instruction environment is described. An outline of methods of courseware distribution and sources for courseware selection are presented, as well as a review of legal opinions on the protection of intellectual property embodied in software and courseware. Uses of the computer as a tool for educational research and for training in the use and production of courseware are also discussed. Appendices include information on acronyms and basic glossaries of computer and computer assisted instruction terminology. (MBR)

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International Conference on Education and New Information Technologies

Château de la Muette
9th-12th July 1984

SOFTWARE AND COURSEWARE FOR A MULTIMEDIA EDUCATIONAL ENVIRONMENT

(Note by the Secretariat)

1. The attached document has been prepared by Yves Le Corre, Professor, University of Paris VII, France, and Jacob Schwartz, Professor, of the University of New York, United States, in their capacity as consultants to the Secretariat. It will serve as a background report for the Plenary session on Theme 2 and Working Group 5.

2. The views expressed are those of the authors and do not commit either the Organisation or the national authorities concerned.

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PREFACE

Since this report has to go into some technical aspects of computers, and of their educational applications in computer-assisted instruction (CAI), the following annexes may be helpful:

-- Annex 1: Acronyms;

-- Annex 2: Basic glossary of computer and CAI terms for readers new to this field;

-- Annex 3: Additional glossary of computer and CAI terms for those wishing to pursue the points made in greater detail.

1. Great strides have been made in applying the new technologies to education, and to training, as a result of the rapid, varied, efficient and economic interactive capabilities of computers. It is these interactive capabilities that need to be exploited for the purpose of analysing, identifying and correcting the learner's responses to different types of situation, such as discovery, learning, testing, reinforcing, creating, applying, practice, etc., using such methods as tutorial, simulation, modelling and routine games.

2. Educational uses of interactive multimedia (CAI in the broad sense) also comprise computer-based learning and training (CBL, CBT) in a narrower sense, such as interactive retrieval from databanks, teaching games, business games, and LOGO (the programming language in which a child can make discoveries from the outcome of the instructions given).

3. At the present time some tens of thousands of hours of CAI time (in the broad sense) are available worldwide, from teachers and also from the thousand or so commercial sources. Dozens of major service companies are working on CAI, as are dozens of publishers, many co-operating internationally, and CAI has about a dozen specialist journals. Something like one hundred newspapers carry articles about it and courseware package assessments. Several governments already have or are contemplating courseware libraries to facilitate exchange of information and packages.

4. The two major criticisms of CAI are high cost and poor quality. Hardware costs have dropped appreciably since 1960 when CAI first appeared, to their present levels of:

-- Viewdata: $200 for black and white; $600 for colour;

-- Home microcomputer: $250 to $1 000;

-- Desk-top computer: $1 000 to $10 000;

-- Mainframe computers: above.

To these must be added the costs of peripherals, a black and white or colour VDU (an ordinary television set if necessary), perhaps a printer, slide projector, tape deck, video recorder, videodisc, sound synthesizer, voice analyser (though so far this can recognise only a few words spoken by the user). A microcomputer with peripherals for classroom use costs between $300 and $3 000. On top of this may also be added the cost of any tele-communications necessary, charged for at local rates for viewdata and slightly higher for the specialist networks. Extra costs are incurred for access to programs, about $1 for viewdata or ordinary databanks, $10 to $200 for many of the micocomputer diskettes and sometimes much more, especially if custom produced by a specialist firm.

5. For the same level of quality, the expense of the central computer has been dropping considerably every year, but the expense of many of the terminals, and of the education products themselves, has fallen much less. The latter depends mainly on cost price and scale of distribution. Costs are high because distribution is on a small scale. Distribution is on a small scale because, even though these products may be of potential interest to considerable numbers of buyers, their educational quality is dubious.

6. This economic consideration can change very rapidly. It is only recently that a few management (not education) packages have become good enough and easy enough to use for sales to reach hundreds of thousands. CAI products are not yet at this stage. However, there are just a few which do perform satisfactorily, on low unit-cost hardware.

7. The following are available on viewdata:

i) Arithmetic and grammar exercises corrected immediately. Depending on how the student answers, similar appropriately-graded exercises may be offered;

ii) Fuller courses, involving the same kind of interaction, though with no branching to different grades of difficulty;

iii) Teaching games, akin to the simplest supplied with a home computer (hardly any animation);

iv) A training course for a basic metals company undergoing industrial renewal (which has its own local network).

Those education packages can run on a home computer.

8. Tutorial education using the microcomputer with a printer or some equivalent kind of display has met with severe setbacks. The first reaction of teachers was to prepare a program representing, simply and individually, what they themselves would say, with requirements they themselves laid down. But a student at a computer does not fit exactly into that situation, and the range of responses available was usually too limited (multiple-choice

questions, words to complete, etc.). However, with progress over the last 20 years, and the advent of sufficiently powerful microcomputers, open-response software can be produced with branching tailored to the pupil's needs and potential. Further progress is still needed in the analysis of responses and of conditional branching before any prototypes can be presented, but some acceptable packages can be found at an accessible cost to the school covering the grammar of various languages (mother-tongue and foreign) and for a small proportion of the secondary curriculum, covering sciences not requiring a graphics capability.

9. Tutorial education with projector and tape deck controlled by microcomputer (no graphic display) provides new possibilities: showing the slide rounds out what the teacher has to say, and offers more scope for interaction. The student can be questioned about it, and say which part of the picture is the answer to the question. The introduction of sound can also enrich the teacher's contribution and is important in a language lesson. Some good packages are available with slides, others with tapes. Packages are available for English and French as foreign languages; combining slides and tape and are very effective, although they have not as yet exploited the full potential of the computer-controlled tape deck.

10. Animation on home computers with colour screens has been developed in the English-speaking countries and more recently in France. Colour and animation add greatly to the scope for presentation, in explaining how many different kinds of processes work. Several dozen packages are on the market, many with very acceptable standards of graphics, on scientific, sociological and economic subjects. One of the most spectacular examples simulates molecules colliding with one another and with the walls of a vessel. The student can vary the volume of the vessel and the average speed of the molecules (and therefore the temperature). Collisions with walls are totalled and measure pressure. Molecule collisions with one another are also totalled over the time period and show the speed of the chemical reaction. Diagrams representing all these changes are very readably displayed on the screen. These simulations are outstanding, though most of them unfortunately do not come with any kind of interactive questionnaire with which to make sure at every stage that the student understands the meaning of every action he takes, what conclusions he ought to be drawing, and the danger in a simulation's departing too far from physical reality. Good quality packages have been produced, requiring some introduction and comment by the teacher using them, in, e.g., physics for higher education.

11. Another type of simulation relies on modelling a process, so that the student can discover its laws. The type described in the above paragraphs could also have used modelling, because the student's measurements show that the pressure in the model varies with temperature, inversely with volume, and with the number of molecules (but does not depend on their mass). "Mini-world" educational programs simulate experimental results in a world where the laws of physics may be different from ours and the student has to discover what they are. Several such packages are currently becoming available and they do effectively rouse the spirit of discovery in a way that no traditional teaching method can match.

12. Simulation is also used to show how various kinds of operation are performed. Several packages are available, some for the home computer: simple repairs (electrical, cars), chemical analysis (qualitative and

quantitative), and how to use a machine tool. Many packages are for more powerful systems:

i) Learning to fly (and to cope with simulated emergencies), with a videodisc or numbered picture generator. It is noteworthy that some home computer reaction-skill games copying these now have exceptionally high quality graphics;

ii) Learning to control a nuclear power station, with simulated breakdowns and problems on the various circuits.

13. Other educational applications have been designed using simpler equipment: the teacher can illustrate his lesson with a home computer as an "electronic blackboard" to display curves, diagrams, data, shapes moving in space. He can present a classroom experiment in which the measurements are clearly displayed through real-time digital processing, and show up the discrepancy between theory and the experiment. Good quality packages have been presented in mechanics, for the study of a few simple movements. That application can be developed by the pupil himself during the practical classes.

14. Still using a microcomputer (or merely a viewdata terminal), the pupil can access a databank and consult it interactively.

15. Another application is learning to read and, in particular, speed-reading. Here the microcomputer uses the possibility of displaying characters for a length of time controlled by the program in accordance with the subject's reactions. A related application is learning to type. Several commercially available packages measure the stroke rate, adjust the pace at which words are presented for typing and then gradually speed up. The packages currently available do not seem to be exploiting the full potential of a system which can not only detect spelling and typing mistakes, but also spot difficulty in typing particular characters or character sequences, and accordingly offer exercises emphasizing the difficult character or sequence.

16. Other interesting educational applications have utilised more complex systems. For example, an English-style analyser sets standard tests and has been found helpful by business users. The system advises on verbal and grammatical expressions to avoid, and where a long sentence would benefit from being divided up.

INTRODUCTION

1. This report deals with the educational applications of new information technologies based primarily on the use of interactive audio-visual systems. The interactivity is generated by a computer which asks the student a question so as to obtain a response which enables it to ask a further question. The scenario is produced by computer-controlled audio-visual equipment, i.e. slides, cassette recorder, video machine, videodisc, display screen, sound or speech synthesiser. The student replies by means of a keyboard, a screen controlled by touch or cursor, voice input, etc.

2. From the educational standpoint, interactivity first means analysing the student's responses: wording of an answer, closeness to a numerical value, how a diagram is modified, what shape is touched on the screen. The next stage in interactivity is the assessment built-in by the author, and selection of the next question or suggestion. Interactivity is also reflected in the possibilities offered the student, such as preference for a particular type of presentation, calling up various kinds of help (dictionary, calculation facilities, different presentation, going back to an earlier stage, an overview etc.). Interactivity is also reflected in the author's built-in decisions on whether or not to meet the student's wishes. These decisions may depend on previously assessed behaviour.

3. The computer and its input/output peripherals constitute the hardware. The audio-visual instructional dialogue developed by the author and structured to take into account the characteristics of the student and his responses in the courseware. The software controls the presentation and reception of the courseware on the terminals.

4. The first experiments date back to the early 1960s, which saw for example the introduction of Computer Managed Instruction (CMI) where the student, on the basis of automatically graded pre-tests and post-tests using multiple choice questions (MCQ), was urged to take a given standard course or revise a particular lesson. These years also saw the launch of LOGO, a computer language for children, and computer-assisted instruction (CAI), which was originally intended for the computerising of programmed instruction but which soon revealed the scope for far more diversified teaching strategies. CAI can be a tool for use by the teacher in the classroom or by the student in school or at home, or a tool for use in continuing occupational training.

5. It should be borne in mind that some other terminology is current in English:

-- CAL for Computer Assisted (or Aided) Learning;

-- CBL for Computer Based Learning;

-- CBT for Computer Based Training.

The present trend is to regard CAI and CAL as covering all the presentation side, independently of educational management itself which comes under the new definition of CMI: information about the student, choosing the educational software to provide, the strategy for branching decisions, the material needed for student and software assessment. Thus computer-based training (CBT) provided by firms for employees covers both CAI and CMI.

6. Today's rapidly advancing electronic technology is making profound changes in the economics of information storage, computing, and information display. We are now seeing gradual development of the necessary hardware for widespread introduction of computer-assisted education.

7. This technological development offers many potential advantages to education: a fresh approach to the costs, diffusion of education to new venues including the home, much improved educational quality in remote communities, the possibility of very wide provision of training in the new technologies, packages which provide sensitive individualised instruction, and detailed information on learner behaviour previously unavailable to the educational psychologist. However, investment will be needed to capture these potential advantages. While video games have grown into a $5 billion industry, computer-aided instruction, which is supported by many of the same technological trends (including cheap microprocessors and high-quality graphics), is still a largely static area.

8. Two main reasons for this difference can be asserted:

i) CAI systems developers have not made effective use of the exciting, fast-paced graphics environment central to the video game industry. Partly because the equipment available to CAI developers has been inferior, typical CAI systems do not integrate all the facilities that would create a favourable learning environment (colour, voice and music output, video images, split-screen and multi-screen displays, etc.). These facilities are not enough to create good teaching but it is noteworthy that, when properly used, they are of great help in getting the educational message across;

ii) The cost of creating high quality courseware is still very high, thus most currently available courseware is mediocre. The cure for this problem will require a substantial up-front investment in improved courseware-writing tools. (Some of what is wanted is outlined in Section V of this report.) It has taken a great deal of effort to realise that a good educational package can be something more than a skilfully programmed lesson on a computer, or interactive reading of a text-book. Educational games, simulation using animation, problem-solving, analysis of arguments emerging from artificial intelligence methods have opened up new horizons which will be discussed further later on, and have shown that certain teaching strategies require the use of a computer. One must also expect production of really high quality software to require TV-studio-like teams incorporating many specialists: subject-area experts, talented teachers, graphic artists, software experts, educational psychologists, and others.

9. A programme aiming to move beyond the present stagnant situation must have three main aims:

i) To create really first-rate interactive multimedia computerised learning environments;

ii) To define and construct much improved courseware production tools (education packages presented and processed by computer);

iii) To produce a number of model lessons constituting new suggestions for top-quality courseware.

10. Although progress on point (ii) will undoubtedly be slowed by the need for serious technical study and by complex implementation problems, choice of just the right project would allow rapid dramatic progress toward (i) and (iii), at least with a few "showcase" examples. This would set computer-aided instruction on the path to the major industry which it is likely to become. But the main reason for setting out the above targets must be the need to ensure that these developments aim in the first place at improving the efficiency of the teaching process.

11. Presently, most CAI courseware designers are attempting to build highly constrained miniature systems which can run on today's computers, and even on tiny personal computers. Even though the commercial pressures that lead to this concentration are clear, emphasis on today's machines is a very poor way of exploring the true potential of CAI technology. To prepare for the possibilities that the next few years will open up, we need to "lead" the rapidly moving hardware "target" substantially, by writing software and creating courseware not for today's machines, but for systems that will be typical five years or a decade from now. It must nevertheless be borne in mind that today we are far from exploiting all the possibilities of existing personal computers, even when the educational packages for which they are provided have been produced on much more powerful computers. We also need to take educational software very seriously and strive to create "classics" which can be used for years in the future by people of very different training backgrounds, ages and motivation, differences that will have to be properly reflected in the way the package converses with its users. Finally, we need to design CAI software systems that emphasize machine independence and transportability in a way that will allow courseware written today to carry forward to tomorrow's superior hardware.

Section I

ADVANTAGES OF INTERACTIVE MULTIMEDIA EDUCATIONAL ENVIRONMENTS

12. The rapidly advancing electronic technology of information processing and display offers many potential advantages to the educator:

i) Most fundamentally, it may allow the steady rise of educational costs to be moderated, through partial replacement of the artisan-like work of teachers labouring in individual classrooms to a more highly profitable system able to make effective use of powerful tools. Failure to deal successfully with the issue of productivity in education must inevitably lead directly to reduction in the real income of teachers, followed by declining student achievement and lagging economic growth. Computer technologies can improve productivity in education. It may be objected, by reference to audio-visual aids, that this argument does not necessarily prove valid in practice. It is worth pointing out that the most commonly mentioned shortcomings of audio-visual aids are:

-- First, the difficulty of rapidly obtaining the film or tape, of scanning it like a book, of adapting it to its target audience and of updating it;

-- Lack of interactivity, so that the student just listens or watches passively.

So long as there is no large volume of educational software of demonstrably sufficient quality, reluctance to spend money on it will be justified. This applies to the initial outlays necessary for developing prototypes, and also to institutional outlays on hardware, telecommunications systems and operation. It must however, be borne in mind that there are already a few good quality educational packages for home computers;

ii) By creating powerful educational packages accessible through interactive multimedia systems both in schools and at home, one can change part of the traditional venue of education, moving it from the school to the office and home. Continuing home education will thereby be strengthened considerably, and education will become less dependent on the centralised school setting. Education will become available in many places, and at

all hours. This is very important for anyone living in isolation, in an inaccessible area such as an island, mountain or desert, and for those who feel uncomfortable in a school environment. The microcomputer can be freely accessible at home or in a library, but it does not seem desirable to contemplate extending that possibility. The school environment has qualities of openness, companionship and discipline which no microcomputer or network could replace;

iii) Although creation of courseware packages sophisticated enough to match the intuitions of a sensitive tutor is a very challenging task, the computer is capable of providing a kind of individualised education very different from the lockstep group progress of the classroom. This can prove a great boom both to the gifted student, who wishes to move ahead at an untypically rapid rate, and to the slower student, who the classroom may presently discourage by depriving him of the explanations he needs once his class has moved beyond his real level of understanding. A properly designed CAI environment can leave the student far freer to select a presentation order and supplementary materials meeting his personal needs than is the case in a standard classroom. Ideally, the computer can be experienced as a sensitive, infinitely patient tutor, able to use exciting graphics and fast-paced styles of emphasis to develop a high level of student motivation. In particular, students found to be deficient in one or another skill can easily be provided with additional study aids and practice material, which can be brought to them in a favourable, informal psychological environment at a time and place of their own choosing. Nevertheless, individualised education is not without drawbacks. The student is not the best judge of the right teaching style for him, and ought to be able to compare himself with his fellow students. The high fliers stimulate the rest and, conversely, are themselves stimulated by the classroom environment. No microcomputer can handle all the students' reactions, such as unstructured answers, requests, doubts or questions. So the student does not try to do anything unstructured, though he might be glad to be able to put questions to a teacher with enough time to listen, understand and inform. Individualised education therefore needs to derive partly from the computer itself and partly from the fact that the teacher, released from various tasks by the computer, can give each student more time, in a relaxed atmosphere;

iv) Computerised instructional systems are capable of collecting an enormous mass of data concerning student response and progress. A student's rate of progress along many separate educational paths -- reactions to particular questions, requests for additional information, and even detailed reaction times -- can all be monitored. This mass of data can be extremely valuable to the educational and psychological researcher: it allows the teacher to diagnose the educational difficulties of individual students; and allows progressive experimental improvement of interactive courseware. By recording and reviewing actual student interactions with a computerised educational system,

detailed information concerning the effectiveness of various teaching strategies can be gained. Naturally, every ethical precaution must be taken. Recordings, even if anonymous, can only be made and conserved with the agreement of the students, parents and associations concerned. The problem is not the same in studying the package itself, or the students of a teacher (himself being tested), or for an individual student identified by name or code. The conditions are not the same when the information medium is held by the student, parents, teacher, school or research centre;

v) As is already the case in many national computer networks, computer systems accessible to large populations can serve as organising centres for many informal associations and clubs of students sharing common interests, taking the same courses, experiencing similar difficulties, wishing to share information, etc. In this way, man-computer interaction can facilitate constructive man-man contact. These points go some way to meet the criticism that computer teaching is dehumanising, a criticism that is largely justified, as only a part of education should be provided by computer;

vi) Computerised systems and communications media allow access to databanks for use in education:

-- Statistics on geography, the economy, society;

-- Local data on the history, development and population of the region in which the school is located;

-- Information on courses, careers, educational guidance;

The same precautions must be taken as with any documentary research: the data supplied must be matched to the student's level.

Furthermore, this possibility creates financial difficulties for the schools, which cannot easily control the costs it incurs.

vii) The student is motivated in his "encounter" with the microcomputer, and will refuse to let the machine have the last word, an attitude which does not wear off with the novelty of using these new technologies. But here again, this artificial encounter which may be more or less appropriately directed must be treated with caution;

viii) With CAI, new teaching approaches can be used, e.g. games, simulation, problem solving, random generations. The computer makes it easy for the student to compare experience with the theoretical model which is supposed to represent a preliminary approximation of reality. Certain concepts can be taught by traditional methods only to students with a marked aptitude for abstraction. By contrast, the computer makes it possible to get these across by means of interactive simulation controlled by the student himself -- this applies, for example, to statistical

concepts (sampling, survey, risk, etc.). This is probably the best justification for using the interactive multimedia. The golden rule should be not to use them if one can manage just as well without them.

13. Here are three examples of education packages which could be produced in a few years' time with existing hardware and software. Comparable but simpler packages are already operational in a number of research centres. Example 1: A classical history lesson is intended to illustrate the power which the capabilities of the new information technology puts in the hands of the courseware designer.

The student, in a college-level world history course, is reviewing the sequence of political events surrounding the collapse of the Roman Republic and the rise of the Principiate of Augustus. Some of the material is presented as straight text, which appears on the screen in an attractive book-like format, with single-frame illustrations, obtained from a videodisc storing up to 50,000 images, occupying roughly a quarter of the screen. This text material is enlivened by occasional (optional) quotations from ancient sources, for example Plutarch's Lives of the Noble Romans, presented in audio, quotations from each such source being read in the voice of a single actor who "represents" the ancient author. This material is announced on the screen by a line reading something like: "Concerning Crassus, Plutarch said the following...". This line appears in a colour which the student recognises as meaning that an optional audio insert is available. If he touches this line on the screen, the video illustration on the page switches to show a bust of Crassus, while Plutarch's remark on Crassus is read in a voice emphasizing its drama and irony. At a later point in the lesson, information concerning the Battle of Phillipi is presented, first by text explaining its significance, date, etc., then by 5-10 minutes of filmed material taken from the videodisc, and introduced by compelling musical fanfare. A map of Italy and Greece, showing the lines of march of the Republican and Antonian armies to the battle, is displayed. This is followed by a more detailed map of the area of northern Greece in which the battle was fought; then by film footage, taken from a helicopter, of the terrain of Phillipi. After this, a brief enactment of the battle itself is filmed, with views of its commanders in action, voice-over commentary on its main incidents, and dramatic scenes of the suicides of Cassius and Brutus. These film-clips then yield to text reviewing the significance of the battle and the events which followed it, with audio statements from ancient authorities reflecting on its meaning from the Roman world.

14. This didactic presentation is followed by an interactive multiple-choice quiz on the material of the lesson, until such time as virtually free responses can be accepted for so complex a subject. Questions answered wrongly trigger reruns of relevant portions of text, of audio, and of captioned video skills. In addition, the student has the ability to make abbreviated extracts of the text, audio, and video material presented, so as to build up his own personalised course summary for end-of-term review.

15. The second example involves simulation, in coaching tennis. The same method could be applied to many other subjects requiring know-how: craft

skills, surgery, laboratory work, etc. Various trial-and-error methods, tested and enhanced in the light of experience, make it possible to represent the movement of THE tennis ball chosen, struck by THE racket chosen with THE back-hand played by the player. Under that impulse, the ball flies through the air and bounces off THE tennis court surface. Other analytical methods feature the player's movement in making the stroke: position and speed of the racket and of certain parts of the body. These features are picked up automatically and processed by computer, in real-time or playback.

16. A data bank contains the characteristics of a number of tennis champions. Computer processing makes it possible, by superimposing an artificial picture, to examine the movement differences in slow motion. The computer immediately displays the remedial assessment of the movement, with immediate information about the success of the student's attempts and gives advice during the action itself. This kind of simulation is of value in other ways, making it possible to study changes associated with the equipment itself. Industries producing a very wide variety of court surfaces see a possibility of obtaining simple measurements with which to make the improvements asked for by users.

17. The third example involves application of artificial intelligence which, though still at the research stage, promises to open very broad possibilities for CAI. It teaches the rules governing the flow of a direct current in a simple electrical circuit. Preliminary analysis had shown that students had several misunderstandings. Some mistakes were due to everyday life analogies such as the flow of air in pipes, of cars on a road network, of people in the corridors of the underground, etc. or comparing the role of an accumulator with a pump, a lift, or again, comparing electrical resistances with other sources of friction or braking. Much confusion and partial understanding is due to those analogies alone. Other types of error also need to be analysed: errors in applying the rules, such as what each of the accumulator terminals does, spatial visualisation of what form the connections take, what the words used mean, etc.

18. A study along these lines can only be performed, even for a very simple case, after statistical analysis covering a wide and varied population. Such analysis is facilitated by monitoring the package to be produced. The resulting package would show the student a few simple circuits and, with the help of appropriate questions, would analyse his thinking patterns. The assessment would be matched with further exercises for the purpose of specifying the student's possibilities or remedying shortcomings.

Section II

COURSEWARE DESIGN

19. In the initial phase of designing courseware, too much attention should not be paid to the technical limitations lest the educator feel restricted by constraints that the computer expert might impose. It is only at the end of this phase of purely education-oriented thinking that what the hardware and the equipment available can and cannot do should be taken into account so that best use can be made of them. It may happen that, because of the technical problems, the courseware has to be modified or the project even abandoned.

20. Before going ahead with designing courseware, it is essential to decide whether information technology will really help or make a contribution towards the desired objectives and to produce a storyboard as a first step in the design process.

a) The Subject of the Courseware

21. The choice of subject is easier when it is a case of meeting a specific requirement, such as training in methods of diagnosis (doctors) or in a particular technique (aeronautics, banking, nuclear power stations), the marking of examinations or achievement tests, research on the learning of reading or writing skills, the production of a complete course (mathematics for 12 year olds, etc.), the application of the LOGO language, interactive interrogation of a databank, etc. Very often, this choice is the result of a sudden idea (local needs or circumstances) in which case the best solution is to follow the advice contained in an author's guide for that particular educational level and see what courseware has already been produced for similar subjects or approaches.

b) Target Audience

22. One of the advantages of CAI is that instruction is individual. The instructional dialogue will depend on the target group, i.e. whether they are children or adults, from an enlightened background or not, with special problems (handicapped, late starters, lonely misfits or delinquents, unemployed, etc.). Not only may the dialogue need to be different, but also the approach. If the courseware is intended for different groups, different pre-tests will help to orientate the subsequent development of the dialogue and other pre-tests could be used to determine the necessary level of revision.

c) Teaching Objectives

23. The teaching objectives must be carefully and precisely defined. The preliminary requirements and conditions should be specified as well as the methods for observing whether the objectives have been achieved. Here is an example given by two French chemists, R. Luft and A. Puill:

> "Confronted with a three-dimensional model of a molecular structure or its conventional graphic representation, the learner must be able to:
>
> -- Analyse methodically the spatial distribution of the atoms;
>
> -- Determine the symmetry group to which it belongs;
>
> -- Deduce the chirality or non-chirality of the molecule and the possible existence of a rotatory property."

24. In creating this particular courseware package, the necessary parameters were:

-- The spatial distribution of the orbital fields;

-- The conventional methods of representing molecules.

Self-evaluation courseware on this subject would also need to incorporate, in addition to concepts in chemistry, different concepts on operators and symmetry groups.

d) Structuring the Subject Matter

25. The author will need to determine the different stages the student has to be taken through in order to reach the desired objectives. This information, together with what the author has already gathered, will enable him to divide up the courseware into separate sub-assemblies, each designed to impart or test one (or possibly more) of the stated teaching objectives. Each sub-assembly may involve the use of particular teaching methods and strategies. Certain of them performing the same function can be designed to suit different target groups or the choice would depend on certain criteria, including individual student preference.

e) Teaching Tactics

26. The educational dialogue can be made more or less open-ended (multiple choice or open questions). The analysis of answers to questions in a numeric or algebraic form can uncover and even correct some revealing errors. Spelling mistakes and certain typing errors can be pointed out and corrected. Certain exercises involving figures, letters or series of characters can be generated in a random manner. This presupposes that the author has a list of the appropriate instructional functions. The LOGO language (apart from its educative character) is a way of learning geometry or the flow paths in a branching structure (grammar, linguistics, etc.).

f) Teaching Strategies

27. In many cases, the literature will define several strategies: for example, the author's guide put out by CONDUIT (consortium of universities in the United States) lists:

-- Drill and practice;

-- Computer-directed dialogue;

-- Student-directed dialogue;

-- Data analysis;

-- Problem solving;

-- Simulation;

-- Model building.

28. Others may envisage a "Socratic dialogue", a random walk through correlated concepts, intelligent problem-solving employing the methods of artificial intelligence used also in expert diagnosis systems. The definitions could be modified in the light of the tasks required of the student.

g) Overall Teaching Strategy

29. Authors must develop sub-assemblies which can bring different strategies into play. They must arrange the linkage between these modules in relation to the characteristics or wishes of the student and taking into account the different responses supplied by the student himself or by others. The overall teaching strategy can be defined as the different activities proposed to or imposed on the student, i.e. observe, recognise, rediscover, analyse, associate, identify, assimilate, deduce, apply, etc. It defines what assistance is provided and what initiatives are left to the student. It incorporates the possibility of tests, checks and conditional branching. It must take into account the likely reactions of the student to different methods of presentation and prepare the details of the educational follow-up (see Section IX) and, lastly, it must enable the scenario to be written making use of the different communication terminals (see para. 40: courseware production studios).

h) Style

30. The style is not the same as for a written or oral course. It is not unlike certain types of audio-visual presentations with the addition of interactivity. Interactivity requires short, specific and clear messages. Key points, therefore, must be highlighted. The student must be made to feel at ease and, accordingly, told clearly what is expected of him and what progress he is making. Where immediate interaction is not required, information can be supplied in a written or audio-visual form already used in education, e.g. supporting documents, film clips, sound recordings, etc.

Generally it is useful to make sure that the different parts of the courseware are comprehensible by testing it on other teachers or students, after warning them that it is still on the drawing board.

g) Pedagogical Portability

31. The author of a courseware package is faced with problems that are similar to and as diverse as those facing other designers:

-- The author of a written lesson must be capable of explaining his intentions in the form of a plan and a written summary;

-- The author of a play may wish to add certain stage directions for the sake of clarity;

-- A composer must be allowed to specify what he wants from the various instruments of the orchestra;

-- A film or television producer must be able to describe his scenarios; and

-- A ballet-master to find a way of representing symbolically the movements and gestures of the various dancers.

32. If two authors are to be able to discuss a courseware package independently of its transcription on a computer, they need to be able to call on certain conventions. This is particularly important when there is no description of the variables or the implicit procedures, e.g. format types, permitted response time and length, loop functions, processing of actions, processing of modules, list of permissable separators for each type of analysis, messages related to certain requests, etc. (reference to the glossaries in Annexes 2 and 3 may make this clearer).

33. It would perhaps be worthwhile to formulate a methodology for producing courseware (even if this were incomplete) which could be adopted as an international standard, but leaving open all the possibilities that authors might require. It would be useful to examine the potential of the CODEVTEL Model (not originally intended for CAI) developed by the ITU (International Telecommunications Union) in Geneva and approved by Member States for training their postal and telecommunications staff. The Quebec Department of Education, following a two and a half year study, proposed three guidelines between February 1982 and March 1983: Guide for Education package assessment; tools for self-assessment of education packages in course of production, and an assessment grid. Converging efforts in the various countries suggest the possibility of international standards jointly arrived at but in no way impinging upon the cultural identity of the individual country.

Section III

IMPLEMENTING QUALITY COURSEWARE

34. Exemplary courseware has been produced even with the limited set of software tools and hardware environments available at present. For example, courses in genetics and chemistry developed at the University of Illinois are excellent. Like many other appealing items in the present stock of courseware, these lesson sequences combine graphics with clever simulations to create lively "mini-worlds" which the student can explore in a variety of sensory modalities. Several lessons explaining basic numerical concepts to very young children, which make excellent use of the touch-sensitivity of some of the terminals, are also noteworthy. Prof. A. Bork of the University of California at Irvine has also exploited the combination of graphics and simulation to produce some particularly appealing material for introductory physics instruction. Far more elaborate simulations, some making use of highly specialised computer-driven optical systems capable of duplicating the appearance of landing strips seen from various approach angles and in various lighting conditions, have been used to produce spectacular civilian and military pilot training systems. Industrial firms have produced much training material in computer-driven videodisc formats. At a more rudimentary level of capability, first-rate drill-and-practice material for elementary arithmetic has been produced by Patrick Suppes' organisation. But, in spite of these and numerous other bright spots, the general level of presently available courseware is low.

35. At present, courseware is implemented largely by "amateurs", e.g. by middle-school teachers or university professors, experts in some educational subject area, but new to the computer medium and generally unable to bring any special artistic concept of graphic ability to the challenging compositions that they undertake. Publishing firms are also becoming interested in the field and are groping for a definition of their role, but have not yet become active on any significant scale, besides which they are accustomed to function more as marketing agents for individual authors than as high-spending producers in the "Hollywood" style that CAI will demand. In a few cases, e.g. Queensland and South Australia, Belgium, Canada, Finland, France and the United Kingdom, some educational courseware is being produced by government bodies, actuated by medium-term considerations and able to make larger investments. Attention must be drawn to the particularly elaborate call for tenders by Ontario Province as part of an ambitious project. But this is still uncommon and in small volume. Only a fraction of the courseware presently available is produced by commercial enterprises able to focus the skills of larger and more expert teams. Moreover, the present efforts of

commercial teams are sharply constrained by medium-term marketing considerations, e.g. the necessity of limiting courseware to what is able to run on the smallest and least expensive of today's home computers.

36. Consequently, most present educational courseware is all too often unexciting, in this regard falling far short of the instructional style that the new technology affords, whose characteristic flavour is still far more visible in video games than in most CAI materials. The mediocre character of presently available materials is reflected in remarks gathered in the OECD survey (CERI/NT/84.02) of new information technologies activities in various Member countries. For example, the Canadian response to this survey notes that: "The quality of currently available courseware is generally inadequate. The general provincial consensus would characterise available courseware as poor or spotty, with only one province rating materials of fair to excellent." The United States response states more flatly that: "The quality of presently available courseware is generally poor." However, a few packages, produced with modest resources, mentioned in the preface, are widely regarded with approval, which shows that the interactive computer dialogue method is already yielding worthwhile results.

37. Vastly better material can be produced, but it should be obvious from the examples presented in Section I, paragraphs 13 to 18 that composition of quality packages will involve the combination of many talents. To choose the points of emphasis and the key pedagogical approaches around which a lesson or course will revolve clearly requires a scholar deeply versed in the subject to be presented, who must also be a talented and sensitive teacher, aware of many possible lines of presentation, and who is able to select the presentation best adapted to the CAI medium. These academic skills must be combined with the skills of graphic designers, with the image-oriented, "filmic" skills of the motion picture director, and with much programming expertise, ranging from a knowledge of symbolic manipulation algorithms to video game design. Actors able to read passages of text with dramatic emphasis will also be needed, and film clips illustrating significant moments in history and recording important scientific experiments will have to be either collected or produced. In some cases, elaborate graphic animations will be the most effective way of making a pedagogical point, so the services of animation studios will be needed.

38. It is clear that production of material of this complexity will resemble the activities of a television or Hollywood film studio more than it resembles text-book production -- a cottage industry by comparison. The kind of person around whom such production will revolve will be a director-like figure, i.e. a talented co-ordinator able to think in media terms, rather than academic. Subject-area scholars will play something like the role that writers play in Hollywood, namely they will generate skeletal, first phase conceptual structures, whose realisation will then require much larger groups with different abilities. The organisation of programmers, animators, and cinema talents which the United States motion picture firm Lucasfilms has built up to carry forward their "Star Wars" series of films shows approximately what will be needed.

39. The production of high quality courseware requires a detailed analysis of the teaching process, which in turn implies formulating precise definitions as regards the structure of courseware:

i) A courseware package is a self-contained teaching package for use

on a CAI computer system and designed to achieve an overall educational objective. A courseware package generally consists of a structured set of dialogues which can be arranged in different ways. In particular, the teacher using such material can modify the linkage between the dialogues;

ii) A dialogue is the smallest coherent teaching unit that can be presented to a student in order to achieve a particular educational objective. A dialogue is an indivisible sub-assembly of a courseware package;

iii) A scene is the organised combination of elementary informative messages for their student. A scene makes use of different sources of information: visual, sound, audio-visual;

iv) An interactive unit is the set of activities making up a student/system interaction decided by the author, i.e., an output of information or a question, reception of inputs from the student, differentiation between question and response, analysis of the response, presentation of the relevant comments;

v) The set of activities enabling there to be an exchange with the student forms the educational situation (e.g. the combination of interactive units and their related decision unit);

vi) The environment is the set of instantly accessible data for carrying on the dialogue and monitoring progress. These data are up-dated by the system automatically or at the author's request during the use of the CAI system by the student. The data are used to monitor the dialogues, the courseware and the students, so there are, in fact, three environments: dialogue, courseware and student environments;

vii) The decision unit, following a calculation involving the dialogue environment in particular, decides on the next step in the procedure (e.g. the next interactive unit);

viii) The link unit is attached to a dialogue and specifies the conditions for moving on to further dialogues, as the environment requires.

40. Studios capable of creating quality courseware need to possess audio-visual facilities like those described (see para. 31) and a stock of educational modules on which authors can draw to avoid having to create each courseware package from scratch or remake commonly used graphics (e.g. measuring instruments, everyday objects, maps, diagrams). The following section discusses the features of (a) the hardware and (b) the software required for computer-aided instruction.

Section IV

HARDWARE

CAI Hardware and Cost Trends

The principal "hardware" elements of future CAI systems will be as follows:

a) Processors

41. For these, the basic "computers" which will supply basic computational power to the CAI systems we envisage, the situation is very favourable. The power of a computer is conventionally measured in standard "MIPS" (millions of arithmetic instructions per second). Typical inexpensive personal computers currently in use supply about 1/10 MIP of computing power. The new generation of 32-bit microprocessors rate at about 1/2 MIP. Other microprocessor chips, now in earlier stages of development, should attain computing rates of 5-10 MIPS by the end of the decade. This should make computers costing a few hundred dollars, roughly as powerful as present scientific computers, widely available by 1990, when they will no longer be the most expensive ingredient in an effective system.

b) High-speed Memory

42. In present technology, the data which computers manipulate, select, rearrange, and display is stored on media having one of two radically different characteristics. Data items, for example numbers used in internal calculations to produce graphic output, which must be available within one or two high-speed computational cycles, i.e. within a millionth of a second or less, are stored on integrated-circuit "memory chips". Other data, for which access delays of 1/10 second are tolerable, is held on rotating storage discs, which resemble ordinary long-playing records but which rotate faster and on which information being recorded magnetically can be erased or stored.

43. The amount of high-speed memory available in a computing system affects its performance significantly. If all of the programs and data needed by the computer can be held in high-speed electronic memory, programming the computer is simplified considerably. If, in contrast, high-speed memory is in short supply, programming is seriously complicated by the need to use more intricate, compressed representations of necessary data, and by the need to move fragments of program and data back and forth between high-speed and bulk memory. Faced with this technical challenge, programmers will cut back on the level of external function which they attempt to supply, and increased

programming costs will limit the range of software products which become available. The result seen by the end-user will be systems which are either less sophisticated, less lively, or both. Hence the cost of high-speed memory, and the amount of it available for program/data storage, is an important factor determining the adequacy of hardware for CAI use.

44. A second important use of high-speed memory in the CAI context is in the "refresh" memory which store images displayed on a graphic screen. These images are built up as matrices of individual dots ("pixels") of specified intensity and colour. A 512 matrix of dots gives a high quality image, and a 1 000 by 1 000 dot matrix gives an excellent, almost film-quality image. If one character or "byte" (equivalent to two decimal digits) is available per image pixel, half of this data can be used to select one of the 16 intensity levels, and the other half to select one of 16 colours. If two bytes are available per pixel, 16 intensity levels and roughly 4 000 colours become possible. Thus, a graphics screen backed up by 2 million bytes (characters) of data will provide excellent, glossy-magazine quality graphics. If this allotment of memory is doubled, then while a prior image is being displayed, the computer can be writing the next image to be viewed into a behind-the-scenes image memory. Switching between these two images then becomes effectively instantaneous, eliminating the psychological irritation caused by visible manipulation of images while they are being viewed.

45. At present, the manufacturing cost of high-speed memory is about $1 000 per megabyte (1 million characters of storage capacity). This is based on the use of memory chips storing 8 000 characters each, which are currently available for about $3 or $4. Improved chips, storing 32 000 characters each, are about to appear on the market. Before 1990, these should be available at about the present price of the 8 000 character chips, so that high-speed memory should be available at about $250 per megabyte manufacturing cost. The 1990 manufacturing cost of 4 million bytes of memory for the very luxurious graphics environment described above, plus an additional four megabytes of memory for program and data storage, can therefore be estimated as roughly $2 000.

c) Bulk Data Storage

46. The bulk data required by an interactive CAI system falls into two principal categories: fixed and variable. Fixed data comprises that mass of recorded text, video, and audio material which the computer driving a CAI system need to retrieve and re-arrange, but not to store in bulk after dynamic re-arrangement. The medium of choice for all this material is digital videodisc.

47. The second bulk data category, variable bulk data, includes student-collected text excerpts, massive intermediate results generated by computer calculations (e.g. "workspaces" of temporarily suspended program runs or simulations), screens full of graphic material held temporarily for later redisplay, dynamically generated audio material held for sub-item selection or replay, etc. This material is best stored on rotating magnetic discs.

48. High quality magnetic storage discs able to hold 20-30 million, characters of recorded information, presently retail for about $5 000. Improvements in recording techniques can be expected to increase this capacity

significantly. By the end of the decade, 200-300 million character discs in the $1 000 to $2 000 price range should be available. Some technological forecasters in this area are predicting even greater improvement in storage density, based on the use of circuit techniques, which might possibly increase the amount of information stored on a disc by factors as large as 100. This will provide variable bulk data storage capacity adequate to CAI system requirements.

49. Videodisc already provides an enormous capability for storing fixed data. Laser videodiscs of the kind recently introduced by Philips, RCA, Sony, Pioneer and various other manufacturers store roughly 10 billion characters of information, equivalent to roughly 5 million pages of printed information, 200 hours of high quality audio, or 50 000 video frames (one hour of live video). Technological improvements over the next decade may increase these already very great capacities by a factor of 10. The cost of individual disc manufacture is somewhere around $5, and quality computer-controlled players are already available for between $500 and $1 000.

50. Future CAI material will in all likelihood be stored on videodiscs, several lessons being stored on each disc. The principal constraint on the number of lessons held on a given disc is clearly the number of minutes of live video required: printed text and computer programs are trivial in comparison. Hence it is possible to store large amounts of supplementary reference material on a disc, provided that only still images, without moving video, are used in these supplementary sections. For example, a student in our hypothetical world history course can be offered full texts of all the ancient authors quoted, biographies and portraits of the historical figures cited, additional maps, pictures of Roman military equipment, etc., all of which can easily by stored on the disc which holds his history lesson. As storage capacity rises towards ten hours of video per disc, it will be possible to store entire courses on no more than a dozen discs.

d) Display Terminals

51. High quality colour display terminals are currently available for $400 to $600. This is already a mass-production price, and cannot be expected to fall significantly over the period we consider. Terminal prices should be largely independent of the resolution provided (given that we count the principal cost associated with higher resolution, namely the larger refresh memory required, separately). Touch sensitivity is not at present a standard terminal feature, but it can easily be provided, e.g. by installing rows of light-emitting diodes and matching receptors around the edges of a terminal's screen, and should add little to the quoted price of a terminal.

e) Audio Output

52. A CAI system can make effective use of two principal forms of audio output:

i) Pre-recorded music and speech

As much of this material as is likely to be needed can be held on videodisc and selected for playback under computer control.

ii) Computer-generated speech

Speech of this kind is generated by transmitting text, possibly written in some special phonetic alphabet, to a speech-generating device which expands it into a standard audio signal. This involves application of some form of "pronunciation algorithm", which uses rules of context to fill in details of the audio, signal pronounced. This level of detail includes customary elisions and transition patterns which are not explicit in the text supplied. To be done well, such "phonemic expansion" requires a small data base representing various "exception rules" of pronunciation. A high-quality speech generator will also handle inflections, allow emphasis, etc. A speech generator of this quality would currently cost several thousand dollars, but it should not be hard to reduce the signal generator and other circuitry required for high-quality computer speech to a small number of chips, which can be manufactured for well under $100.

53. The technology used for speech generation should also support production of computer-generated music, making elaborate orchestral effects available to the courseware designer, at little or no additional cost.

54. The above list of peripherals is not exhaustive. A computer is usually linked to a printer and sometimes to a plotter. Input may be by keyboard, tablet, touch screen, mouse, joy-stick or even voice analyser.

Portability Between Different Hardware

55. It is important to ensure courseware portability as between different hardware of comparable performance. Compatability of the interfaces is essential and account must be taken of the numerous differences there are:

-- Type of keyboard: QWERTY or AZERTY, accents, function keys;

-- Type of information medium: size, sector pattern, density;

-- Type of screen: number of lines and columns, character definition (semi-graphic, alphanumeric), colour, graphic functions;

-- Type of connection to peripherals: series/parallel, V 24 socket, Peritel socket;

-- Type of central processor.

56. Portability is possible between microcomputers operating with the same microprocessors but this is not always the case. Moreover, there are currently four different levels of CAI system in use:

i) Videotex terminals;

ii) Personal microcomputers with viewer, small printer and cassette recorder;

iii) Microcomputers with larger peripherals;

iv) Minicomputers or mainframe computers.

57. Courseware authors should use the largest-capacity configurations providing access to a number of databanks. The courseware itself should be operated on a high level configuration comprising the microcomputers and terminals described above. However, the lack of uniformity between processors and peripherals creates difficult problems of portability and compatibility. The situation becomes even more complicated if it is wished to run a simplified version of the courseware on less sophisticated configurations.

58. The functions usable for the instructional dialogue are insufficient in the case of videotex and of a fairly low order in the case of 8-bit microcomputers, but the situation is changing rapidly and the above four levels could well be reduced to two. Videotex systems are starting to use microcomputers as their "intelligent" terminals and microcomputers now incorporate 16 and even 32-bit processors.

59. From the user's point of view, the best solution will in many cases be to have, like the authors, microcomputers connectable to more powerful computers so as to:

i) Have no difficulty in using the latest courseware versions;

ii) Be able to make use of ancillary resources (operations requiring substantial computing power, vast arrays of data requiring frequent updating);

iii) Be able to consolidate the results of sessions and thereby improve courseware by the fine analysis of these results;

iv) Be able to consult and try out existing courseware packages.

Section V

SOFTWARE

60. Courseware must:

-- Be easily modifiable (corrections and essential updating: a courseware package is a "live" product);

-- Be adaptable for different audiences (large target audience for cost-effectiveness reasons). A package can be amortized just as well over time as over users;

-- Continue to function satisfactorily after modifications (there must be absolutely no need for debugging);

-- Be "readable" by the instructor who proposes to use it.

61. The courseware is controlled by a computer program -- the "software". The software controls: I. THE QUESTION AND ANSWER SEQUENCES and II. THEIR PRESENTATION VIA THE AUDIO-VISUAL ENVIRONMENT. It may be written either in a general purpose and, if possible, standardised computer language (e.g. PASCAL, MT) or with the aid of an author-system involving specialised editors and a quasi-natural language form.

62. It should be noted that the question concerning the precise functional capabilities most necessary for the composer of courseware at various levels of sophistication and the manner in which these can most adequately be provided is the subject of active discussion among technical experts in this area. Although many would agree with the stress which the present report lays on development of an authoring system, A. Bork, however, has successfully developed first-rate packages using standard-general-purpose languages like FORTRAN and PASCAL, and would maintain that no specialised language is necessary. On the other hand, many authoring systems are in current use. Since all other major fields of computer application, e.g. commercial programming, word processing, mechanical engineering, simulation etc. have developed languaged and tools to facilitate their activities and make them more readily accessible, the authors of the present report expect the same to be true of the courseware writing field as it grows.

63. It should be noted that few of the capabilities which have been described as essential for courseware writing, e.g. animation, video output, computer-generated speech, input from a touch-sensitive screen, are either

provided in general-purpose languages such as BASIC, PASCAL, or LOGO, or relevant to these languages. Note also the distinction between courseware writing languages devised for use by the authors of courseware (e.g. educators or programming technicians working with them) and languages for student use devised to facilitate instruction in programming and computer science. LOGO is a successful example of languages of this latter type, and has attained real educational success by packaging such important concepts as procedure construction and manipulation of geometric rather than numeric concepts in a form accessible to the beginning student. Though important in their own right, these languages, when seen from the point of view of the present report, merely illustrate the general importance of proper programming tools, and can be regarded only as specialised instructional facilities, which need to be made available for invocation by courseware authors within the framework provided by a generalised authoring language.

I. CONTROL OF QUESTIONS AND ANSWERS

64. Except in rare cases, therefore, authors of educational material should not attempt to "program" but should define their intentions and provide instructions in the form of a description of the "dialogue structure", indicating general operations for controlling the interaction with the student: analysis of messages (replies or requests). In this sense, therefore, high level instructions of this kind, which initiate complete and specific CAI operating sequences, are not covered by standard algorithmic programming languages but instead are new modes of expression more akin to statements than instructions. These modes of expression used in some "author languages" are gaining ground and are clearly one, if not the only, way of overcoming the problems of computerising the courseware developed by teachers.

65. Potential authors should have access to a "dialogue bank" from which they can extract material and thus not have to compose each courseware package from scratch. By the same token, banks of educational data such as illustrations, exercises, etc. also need to be set up.

66. Compiling these "courseware banks" means, of course, first of all developing a general methodology; without going as far as standardisation, it is important to select a minimum number of basic tools for use by every author and to identify the common features in all instructional dialogues irrespective of their particular educational strategy. This is in line with the general direction of current trends widely recognised as being valid in other computer fields -- that is to say:

i) To provide designers with software tools that operate high level logic models;

ii) To encourage designers to structure their material (in their own and the user's interest).

67. It is therefore clear that, for CAI purposes, computer experts have to create a whole architecture of resources. Producing such application systems is obviously helped by the progress made in software engineering and the experience acquired in areas such as computer-aided design and data bases.

However, this know-how and these techniques are not sufficient to satisfy all identified requirements for three reasons:

68. The first is that, unlike what is usually the case in other areas, the end-users (i.e. the "students" in the broadest sense of the term) can be anyone at all, which means in particular that interactive sequences must be in natural language.

69. A second reason is the fact that the system has to communicate with highly differing categories of user. Apart from the students who are the main category, there are also the authors of the courseware and the teachers who use it. Even if the same person combines these last two functions, these are two quite distinct roles with quite separate requirements as regards the system's resources.

70. The third reason is the extreme variety of resources which need to be deployed simultaneously since education, by definition, concerns every discipline, every level and every technique. Just the incorporation of this vast range of resources, which is constantly growing not only in size but also in variety, is in itself a major problem.

71. The systems that have been, or are being, produced have already brought improvements in software in a number of different directions, which can be classified in terms of two main problem areas:

a) Problems of natural language communication (man/machine dialogue); and

b) Problems of constructing and manipulating complex objects (composition and creative operations in a conversational mode).

A. Communication: Man-machine Dialogue

a) Student-machine Dialogue

72. As we have seen, the CAI audience is extremely varied in age, socio-cultural background etc. Using a computer terminal has to resemble as closely as possible a normal interchange between individuals, even if this interchange involves the use of audio-visual, graphic or other types of aids; there can be no question of having to learn complex and arcane procedures, as might reasonably be expected of specialised staff (computer experts or others) working on a screen. In fact, the tendency now is to employ a "user-friendly" approach even in the case of specialists -- in other words, to make the user at ease by ensuring that he is addressed in the form of complete, plain-language messages that accurately describe the situation and that the computer shows a considerable capacity for "understanding" the messages it receives from the user. For instance, "menus" are increasingly common, which unquestionably make life easier in many simple cases. As far as CAI is concerned, however, this solution is totally inadequate as a means of expression for the student, short of getting bogged down in "multiple choices".

73. Analysis of student semantic responses is an area of great importance. Student responses typed at a terminal can be regarded either as character strings or as word sequences. Some systems make use of these to analyse numerical, algebraic or textual answers:

-- Analysis of numerical answers may accept a certain percentage of deviation from the exact value and interpret unit changes;

-- Algebraic analysis accepts different but equivalent forms of an expression;

-- Textual analysis recognises words, even when typed if required (upper/lower case, presence or absence of additional spacing, incorrect punctuation, etc.).

Unless an exact match is specified, words will match if a standard spelling-error algorithm judges them to resemble each other closely enough to be regarded as misspellings of each other. A combination of words consists of a given sequence of words, including "ignorable" words which may appear in the student's input text but will be omitted in the assembly operation.

74. A word pattern consists of a specified sequence of words, together with a set of "ignorable" words which can appear in the student input but will be ignored by the matching process. The individual items in the Q sequence are actually sets of logically equivalent words, any one of which is acceptable in a given position. The match operation can specify either that all words in the student input must appear in the pattern to which the input is matched (full match) or that a subset of the input must match the pattern (subset match). It is also possible to specify either ordered match (in which case words must appear in the student input in the same order in which they appear in the pattern being matched) or unordered match (in which case the elements of the pattern can be arbitrarily permuted without disturbing the match).

75. All this is good as far as it goes, but deeper methods are urgently required. Current research in computer analysis of natural language is steadily extending the ability of computer programs to deal with unrestricted natural language input. However, this ability is still highly imperfect, and may not be usable at all until it becomes entirely solid. Even if a computer handles 90 per cent of a student's natural language inputs adequately, bizarre reactions to 10 per cent of these inputs, or even inability to produce any reaction, may create an unnerving pedagogical environment, which often forces the CAI designer to prefer multiple-choice inputs chosen from a pre-restricted menu. For this reason, and also because of the presently very high computational cost of natural language input, we can expect the use of such input in courseware to develop slowly.

76. In the case of a narrow subject matter, however, it is possible to allow the student to express himself naturally or, at least, substantially reduce the constraints and virtually eliminate input instructions: in such cases, knowledge of the context should make it possible at any point to analyse accurately and rapidly the input from the student (e.g. with less than 1 per cent misinterpreted responses). This does, however, mean compiling a fairly precise typology of situations and meaningful "objects" (type and form). While it is always the author's responsibility to define exactly what he is looking for in the student's input, it is the program-writer's responsibility to work out and provide the author with:

i) High powered facilities for describing research "models", which are easy to write and read back;

ii) A limited number of well-differentiated, high-performance analyser modules (with a message analysis time of about one second).

77. Fundamentally, these problems are not confined solely to CAI, but in other data processing areas these vocabulary limitations and constraints (resulting from the use of technical jargon) have not so far proved the drawback they present in the case of education, where the process is more one of "constructing" than "designating" and where the messages processed cover a vast semantic field.

78. The lessons of experience to date highlight the need:

i) To clearly differentiate between message "production" and message "recognition"; what interests most the designer of a dialogue is the meaning of the student's input, not the way this input is produced: for example, the student can indicate the co-ordinates of a point by typing numbers on a keyboard, by positioning crosslines on the screen, by moving a cursor by means of control keys, by indicating the point on the screen with a light pen, by speaking the numbers into a microphone, etc.; the author, on the other hand, has to identify the point in his own logic design, e.g. a set of two numerical co-ordinates; clearly therefore standard interfaces are needed capable of feeding the analyser selected by the author from any input from the student;

ii) To design separate analysers depending on the type of object sought in the student's input; different processing is required for identifying textual expressions, numerical expressions, formulae, etc.; each object has its own structure and its own coding.

b) Teacher/machine Dialogue

79. In this case, the problem is one of specific "editors" which enable the teacher to define the content of the dialogue or to modify it. Here again, the need is for clear differentiation of the objects being dealt with: text (character string), screen displayed text, diagrams (graphics), etc. and the combination of these objects.

B. Construction and Manipulation of Complex Objects

a) Creation of Courseware

80. A courseware package will inevitably be a complex object if the author's intention is to create a product which is open-ended and coherent. It is essential therefore for the author to be able to design his software as a highly structured object, with each section or sub-section as independent as possible so that it can be re-used or modified. For this reason, a courseware package should take the form of a series of "dialogues" with a conditional linkage so as to allow selection if individual flow patterns. It will thus be very easy for a teacher to adapt an existing courseware package:

i) By simply rearranging the dialogues in the courseware;

ii) By deleting dialogues or adding other existing dialogues;

iii) By incorporating a dialogue of his own composition or by substituting it for an existing dialogue.

In order to do this, a standard mode of expression should enable the course of events to be described by means of a "flow chart" indicating what is happening at any given moment. Decisions will be taken in the light not only of local requirements but also of the "checks" prescribed by the author.

b) Processing of Instructional Inputs

81. The educational items are regarded as manipulable (selection, combining, sorting, looking for correlations, etc.). Such operations can be preset once the usual presentation problems (variable automatic formatting, summarising, etc.) have been solved.

II. MANAGEMENT OF THE AUDIO-VISUAL ENVIRONMENT

82. The CAI environment described in the preceding pages combines graphics, voice output, music, video, major textual and image data bases, and very sophisticated software. To facilitate the creation of courseware of this flexibility, authoring systems which make many capabilities available to the courseware designer will be required. The list of desirable capabilities is long and still being worked out, in an environment of constantly changing technologies and costs. Although this makes definitive statement of the required capabilities difficult, we can at least list some of the facilities most likely to prove broadly useful. These include: two-dimensional text output, in a variety of alphabets, fonts, letter sizes, and character orientations; two dimensional graphic representation of three-dimensional figures; animation, and in particular multiple animated "sprites" of the kind used by video-game designers; video output in still-frame and continuous-play modes; electronically generated audio-signals; high-quality computer-generated speech; audio playback of narration and music. (Note that the development of high-power graphic chips may make it feasible to use very high quality 3-D "syntavision" images.) In addition, an effective CAI language should support input from a touch-sensitive screen, and from various kinds of "tablets", "joysticks" and "mice", which can be used to pass graphic information to a computer. These facilities should support various useful forms of "rubber banding", i.e. for drawing lines and other figures which stretch and shrink dynamically as a student's finger moves on a touch-sensitive screen. In addition, powerful response-analysis routines and general-purpose computational facilities will be required.

83. In regard to the technical problems of implementing first-rate courseware rapidly and inexpensively, the appropriate tool is a powerful, transportable, standardized, very high-level CAI language that is easy to use. Even though current CAI authoring languages suggest features desirable for such a language, none of them are well-organised or transportable enough to serve as such a language without very major changes. Experimental work on such a tool, pursued in an environment providing first-rate hardware, should

be regarded as a main developmental priority over the next few years. The following paragraphs comment on some of the facilities which such a language will have to support:

a) Powerful General-purpose Computational Facilities

84. Courseware will occasionally need to make calculations of the sort supported by general-purpose algorithmic languages, for which reason an authoring language should make all the facilities of a powerful algorithmic language available. These should include flexible string manipulation and analysis operators, pattern-analysis mechanisms, operators facilitating use of general tables and maps, and a capability for handling very general composite objects, for example, internal representations of the shapes of complex geometric bodies. New types of objects should be definable by the courseware writer. Since some of the operations used in CAI languages will have numerous inputs, many of which remain constant over several successive invocations of the operation, partial pre-processing of these inputs is a useful facility. Since simulation-based lessons can be expected to be common, simulation-oriented parallelism, i.e. the ability to define various semi-independent event streams which the computer can push forward more or less simultaneously, is a semantic facility which is important to provide. Finally, since it is so powerful a tool for response analysis, generalised backtracking, i.e. the ability to carry out computational activities provisionally but to eliminate all their effects when and if they prove fruitless, is a desirable semantic mechanism.

85. No existing CAI language fully supports all the facilities listed in the preceeding paragraph, even though a modest general-purpose computational capability is available in all CAI languages.

b) Response Analysis

86. It may be possible to develop inexpensive speech-recognition chips which can deal adequately, with very limited classes of utterances, e.g. "yes", "no", numbers and letters, etc. This could be a valuable adjunct to touch-sensitive screen input, and should be supported by a coursewriting language if and when it becomes available.

c) Various Types of Specialised Editors

87. Here the question is not of improved text-editors, of which a great variety are already available, but of editors which facilitate the composition and manipulation of graphic figures. Valuable design ideas for editing systems of this type can be gleaned from various "electronic paintbrush" systems now available to artists interested in computer graphics.

C. Some Possible Developments for the Future

88. It is worth emphasizing that the preceding discussion of CAI software tools is deliberately humdrum. It emphasizes software facilities that can be developed now, and by intent, ignores many exciting software and courseware possibilities having too large a research component for their immediate

construction to be straightforward. To redress this perhaps overly pragmatic attitude, it is worth describing a few of these more speculative possibilities. Some of these relate to our steadily improving, although still imperfect, ability to process natural language.

89. For example, a natural-language parser might work with grammar, comprehending both the constructions of standard natural language and those of other less "literary" language versions which students tend to use. Sentences in compositions which were not quite grammatical could then be parsed, and trigger either review of the grammatical rules being violated, or paraphrases of the offending sentences which cast them into literary form. (A parser of this sophistication could also work out sentence diagrams for the student's edification.) A somewhat more sophisticated parser might also be capable of detecting common faults of style, e.g. the use of passive constructions where shorter active phrasings are available, and might be able to generate various improved reformulations of a user's sentences for his inspection and possible adoption. Though it would have to operate at a much more sophisticated syntactic level, such a program could be regarded as a syntactic analogue of the spelling-error detection programs that have now become common.

90. A wave of enthusiastic attention is now focusing on so-called expert consultant systems, which attempt to diagnose real-world situations, assigning each such situation to one of a finite number of diagnostic classifications by asking sensibly ordered sequences of questions. It is hoped that systems of this sort will be capable of imitating the investigative model used by human experts closely enough to approximate expert behaviour. If this hope proves justified, it may also prove possible to use these systems to compare expert behaviour with novice behaviour, and e.g. to automatically critique students in analytical chemistry or medical diagnosis classes for asking questions that are probably irrelevent, or for attempting laboratory manipulations which an expert would refect as being unlikely to succeed. These intriguing possibilities relate to the broader question of the extent to which CAI systems can develop valid models of a student's skill inventory and cognitive biases. To do this will obviously not be easy, but to the extent that such an attempt succeeds, CAI systems will come to behave like sophisticated, infinitely patient tutors (cf. Section X, artificial intelligence, para. 121).

D. Courseware Portability

91. Some courseware can only be operated on hardware configurations designed specifically for CAI and are therefore not portable to other configurations. The cost of producing satisfactory courseware currently ranges between $10 000 and $50 000 per hour. This cost can be substantially reduced by authoring systems linked to courseware banks. It can also increase if the services of television or computer animation studios have to be used. It is important that quality courseware designed for a wide range of users should be compatible with the different types of hardware they may have. Mention has already been made of the benefits to be derived from ensuring the educational portability of software as well as its portability on different terminals. A further requirement is that the controlling software should also be portable. Yet another prerequisite (to be considered later in this paper) is that courseware follow-up should also be portable, which in turn means portability of the relevant software.

92. Certain countries rely solely on hardware for portability: Alberta,

Canada has chosen Apple; Great Britain has chosen the RML 380Z, the BBC Micro and the Sinclair ZX Spectrum; some US States and Canadian provinces have gone for PLATO hooked up to a CDC computer or on its own with the micro-PLATO. Another way of ensuring software portability is to write the courseware in a computer language such as BASIC or Pascal. However, there are several versions of these languages, which depend, what is more, on the type of hardware that supports them. Some countries have adopted a particular version: Denmark and Ireland, for example, use COMAL 80. An attempt has been made to standardize some of these languages (e.g. Pascal USCD, the choice of several states in Australia). But this does represent a considerable advance on the proliferating versions of BASIC (not to mention its graphics and sound extensions). International cooperation might be useful in standardizing at least the core of a number of computer languages useful for CAI. This could lead on to some degree of hardware standardization.

93. However, in this case, portability can be incorporated at the level of the Operating System, e.g. CP/M or MS/DOS which then become virtual standards for microcomputers. Failing this, translations are made, with varying degrees of success, from one language to another. Run-time hardware interpreters and emulators represent partial solutions more in use. It is anticipated that this rapidly developing technology will evolve new solutions in future. It is noticeable in fact that the manufacturers work to a limited number of standards. Until then, rewriting software as necessary is likely to be the solution for software developers.

94. A different method is to represent the courseware as data for processing. The data for CAI a lesson may need reformatting, but this is considerably easier than if each lesson were a program requiring translation to a new programming language or conversion to a new computer system (McDonnell Douglas).

95. Another solution is to use a standardized internal representation at computer level. One instance is the DIANE Project in France. Portability is ensured by using some 150 standardized capabilities to incorporate the educational content. The internal representation includes no implicit instructions, imposes no teaching strategy and will support any desired extension. It therefore guarantees portability. Conversely, it makes it harder for the author to express material directly (and does not guarantee educational portability). There are two independent methods of correcting that defect: either to use special purpose editors for amendment, output and folllow-up or to use a language form in which the author can describe his data within a structure in which he is no longer obliged fully to describe the usual instructions. Those instructions are specified as part of the teaching strategy freely chosen by the author.

Section VI

DISTRIBUTION OF SOFTWARE AND COURSEWARE

96. The distribution of courseware has to contend with all the problems of distributing written documents and audio-visual sequences with, in addition, the problem of distributing the software which manages this environment and the question and answers sequences. There are several methods:

a) Distribution by Network Transmission

97. Software can be distributed by dispatching the media on which this is recorded (cassettes, diskette, tape, PROMS, videodisc). However, software is now frequently distributed by network transmission, with the result that there is a temptation to arrange for distribution a substantial proportion of the courseware data by the same method. It is important to be able to do this for at least the more active parts of the courseware, i.e. the dialogue logic and courseware follow-up (see Section IX). This method of distribution is also worth considering when the courseware makes use of databanks. Sound, text, graphics and software can be transmitted over the ordinary telephone network (switched network) or more rapidly and more reliably by special high through-put networks (coaxial cables, optical fibres, etc.) Naturally, here again there are problems of portability:

-- Compatability of the different media;

-- Teletype compatability if the telex network is used;

-- Standard interface fitting the network (e.g. interface X 25).

b) Distribution by the State Education Services

98. In many cases, users in the state education sector have taken steps to organise the distribution of courseware, usually independently of the already established distribution channels for educational audio-visual material. In the United States, the universities consortium (CONDUIT) distributes post-secondary level courseware. In Australia, most of the states have a special service which goes under a variety of names, e.g. Educational Media Service, Educational Technology Centre, Education Department Computer Centre, and Computing Branch of the Education Department. In Canada, distribution is handled by the department of education in a number of provinces (Alberta,

British Columbia, Ontario and Quebec, in particular) and some courseware packages are distributed via the Telidon videotex system. In the United Kingdom, distribution is organised by the MEP (Microelectronics Education Programme) and the SMEP (Scottish MEP) via regional centres. The Council for Educational Technology (CET) and the MEP have set up a central information service called CEDAR (Computers in Education as a Resource). The BBC Computer Literacy Project distributes its own courseware and the BBC has a telesoftware distribution service using Prestel videotex, which can feed courseware into school microcomputers. In France, the education department's computer unit distributes cassettes of courseware produced by teachers. The teaching profession has also set up a freely available mail order service for distributing both the education department's courseware as well as that produced by educational publishers. Distribution has been handicapped by the difficulties involved in making large numbers of copies of diskettes. A number of courseware packages are distributed by the Musée de la Villette via the Teletel videotex system.

c) Distribution by Private Undertakings

99. Educational publishers distribute courseware through their normal distribution channels. Several hundred other firms in the United States and several dozen in Europe produce and distribute courseware which can be run on specific types of microcomputers. In many cases, distribution is handled by microcomputer sales outlets. Shops have been set up similar to "videoshops" but specialising in courseware. Courseware material can also be distributed via the telephone network: in France, Didao-Bordas are planning to distribute 350 hours of courseware ancillaries to school textbooks via Télétel. This courseware can be used on a videotex terminal (or TV screen) or loaded onto a microcomputer. Courseware documentation can be included on the same diskette as the package itself. But if the documentation is voluminous, or needs high-quality layout, it should preferably be printed. The difficulty of reproducing material printed in colour also helps to safeguard the whole package against pirating.

Section VII

PROTECTION OF RIGHTS IN SOFTWARE AND COURSEWARE

100. If the courseware industry flourishes in the manner predicted, it will create major economic interests in a mass of publishable software, visual materials, music and so forth. It will therefore be most important for the relevant legal authorities to establish a framework of statutes and administrative regulations conducive to the active and unobstructed development of this material. The legal issues involved are quite complex, and still not clear, even after many court trials in the United States and Europe. The basic problem is to reconcile two aims: on the one hand, freedom for development of general mathematical or combinatorial principles applicable in many circumstances and to a wide variety of systems, on the other hand, protection for some specific products.

101. This makes it necessary to answer questions such as: when is one computer game, or one graphic display, or one interactive question-answer sequence, close enough to another to constitute an infringement of rights in intellectual property, given that the actual technical embodiments of these materials can vary greatly. Note here that computerised instructional material will partake partly of the character of films, partly of the character of music, partly of the character of a book, and will in part have a highly technical character for which claims of increased efficiency in the execution of previously known procedures will be crucial. It may be claimed, for example, that even though none of the separate elements combined in a program are unique in and of themselves, their combination is unique and hence deserving of protection. Problems of this sort have of course had to be faced in the publishing and film industries. If we create a successful series of detective stories based on a lean pipesmoking detective with a physician companion, and you copy our format changing only the names, can we sue you? Can we sue you if you write new stories involving characters having the same names and attributes? Although long familiar with these questions, the courts will now have to face them in settings much complicated by a wide range of new and extremely plastic technologies.

102. Though this report can of course make no detailed statement concerning this difficult juridical problem, a brief review of legal opinion in these areas will show complexities that the courts have faced in trying to deal with protection of intellectual property embodied in electronic forms ranging from circuits to symbols recorded on magnetic, optical, or other media.

103. Protection of software has been sought through laws governing patents,

copyrights, and trade secrets. However, till very recently patent protection for software has generally been denied, often on the grounds that programs or computer algorithms do not constitute a patentable industrial "process" in the sense of typical patent laws, but are instead more akin, if large and composite, to published literary works for which copyright rather than patent protection is appropriate, or, if succinct and algorithmic, to mathematical formulas, which are not patentable. In particular it has been held that the mere application of a computer to implement a process or procedure previously known but realised in some other form does not constitute a patentable invention.

104. On the other hand, the courts have been reluctant to rule that data having electronic form, for example a microprogram represented by a pattern on a silicon chip, could constitute a literary work ("work of authorship") to which copyright protection could be granted. For example, the Unites States Supreme Court has held that no copyright infringement was created by publication of a perforated roll for an automatic piano which, when operated, exactly reproduced a copyrighted work of sheet music: this on the grounds that the perforated roll was not "in form which others can see and read". Based on this precedent, a similar judgement denying protection was delivered in 1980 in a suit claiming infringement of copyright in regard to a computer chess game. Very recently, however, the United States courts have ruled that computer software, whether it appears on a floppy diskette or is etched on chips, is protected by copyright laws. This decision, delivered in September 1983 in a suit between Apple Computer Company and the Franklin Computer Corporation, contravened Franklin's claim that operating system software embedded in ROM microcode could be copied freely. Nevertheless it must be realised that the protection created by this ruling covers only the copying of fully detailed software, not the imitation of more general graphic strategies, question/response and lesson sequencing patterns, etc. protecting all of which may concern a courseware company as much as or more than detailed code sequences.

105. In regard to protection under legislation governing trade secrets, the problem has arisen as to what exertions are necessary on the part of a company wishing to claim such protection if their claim is to remain valid, and the extent to which such exertions are compatible with a general public interest in the diffusion of technology. Is total nondisclosure of a technique or process a necessary condition for securing trade secret protection? If not, what is the permissible breath of disclosure, e.g. does public viewing of the human-factors content of a graphic system, computer game, or CAI lesson void this type of protection?

106. Action by competent and technologically sophisticated legislative, administrative and juridical bodies is clearly needed to sort out these questions.

107. When a programme is written in a particular language, it is not at present protected if it is reproduced in another language, particularly if it is adapted to another type of hardware. Courseware protection may cover the following four components:

i) The teaching strategy: This is embodied in a flowchart separate from the texts or images presented and represents a considerable programming effort. It is easy to compose a "new" courseware

package simply by changing the texts or the images;

ii) The set of dialogues, i.e. all the possible displays included in the courseware;

iii) One particular dialogue, i.e. a modular unit of the courseware -- an indivisible component which forms a whole and which, as such, can be used in another courseware package. Courseware production studios have a bank of such dialogues;

iv) The still images and the supporting documents covered by the ordinary copyright laws.

In the case of these four components, what needs to be considered are laws of appropriation, adaptation and translation.

Section VIII

OBTAINING COARSEWARE

a) Courseware Specifications

108. Catalogues of school textbooks describe them, state for what category of students they are intended and reproduce the table of contents together with several pages of text. These catalogues can be used to select a textbook on a given subject for a particular grade. By contrast, catalogues of scientific films are much more difficult to compile and use -- it is not easy to gauge whether a particular film will in fact be interesting, of the right standard and capable of holding the classes' attention, and to know whether it is self-contained or whether the teacher needs to prepare a suitable introduction. (The Departments of Education of the six provinces of Canada produced a "Joint Provincial Courseware Cataloguing and Indexing Project" in June 1982 in order to define the cataloguing and indexing method having regard to the different information channels.) A catalogue should be laid out differently depending on whether it is aimed at a decision-maker whose task it is to define the measures to be taken to acquire an education package library, or to the classroom user.

109. Courseware catalogues are even more difficult to compile. Perhaps one answer would be to use the CODEVTEL classification (cf. Section II, para 27) amended and amplified to include the details required by the teacher or student, e.g. subject matter, aims, standard, target audience, potential uses, strategies, interactivity etc. It would be desirable to follow some standard model for these specifications.

b) Information on Courseware Quality

110. The customer needs to be protected against misleading advertising. The State of Florida (Senate Bill Section 283-25) insists on a data collection and analysis test before a courseware package may be put on the market. A consumer association evaluates courseware by means of the EPIE (Education Projects Information Exchange) and publishes its findings in an information letter (Microgram).

111. We expect the rapid diffusion of computer equipment to schools and homes to bring increasing masses of courseware onto the educational market. As this happens, the role of agencies able to provide schools and individuals with informed judgements as to the quality of these many offerings will grow.

Some assessments of this kind are already being provided by public authorities and by nationwide organisations of educational computer users like EDUCOM in the United States. Systematic strengthening of organisations of this kind seems desirable, as does the development of international links between various regional and national courseware diffusion and assessment bodies.

112. The function of software reviewers writing in the technical press is growing in importance, e.g. the New York Times now runs a weekly column entitled "Personal Computing" which regularly reviews not only instructional programs, but also word-processing packages, financial planning aids such as VISICALC, data-based systems for personal computers, etc., commenting on their ease of use and general quality. Consumer-oriented computing magazines like BYTE and Personal Computing publish increasingly voluminous material of this same type. Informal user comments on software systems also circulate actively and very rapidly through various electronic "bulletin boards" established within major computer networks such as ARPANET.

113. The Allenbach company publishes "Software Reports" and provides assessments and guidance on choice. These assessments are compiled after consulting teachers, parents, and students and processing their replies on a computer. This material, prepared by authors and distributors, should include a technical specification for the user indicating the subject (level, knowledge required) and also the hardware (peripherals, support operating system) together with a "quality" record dealing with teaching strategy, presentation and follow-up. A simplified representation of the package flow chart for the teacher is highly desirable. These specifications are not the same as the validation records produced from users' experiments.

c) Shopping for Courseware

114. The best way of picking a book is to browse through it, glancing rapidly at a number of pages and stopping whenever something catches the eye or attracts the attention. This is hardly possible in the case of courseware. A few typical extracts from the instructional dialogue and a flowchart describing the teaching strategy provide useful but insufficient information. Preferably, therefore, courseware should be accompanied by descriptive literature designed either for teachers or for students.

115. In Great Britain, the CEDAR Project (Computers in Education as a Resource) has prepared a videotape containing key video sequences from a hundred or so preselected courseware packages. CEDAR circulates various information on English-language courseware and sends it to the fourteen MEP (Microelectronics Education Programme) Regional Centres, where it can be consulted. In the United States CONDUIT produced a magazine called PIPELINE until 1983, and now issues catalogues by subject or computer language. Some packages can be described in a one or two page abstract, with photographs of illustrations and graphics on the display screen.

etailed Assessment of Courseware

116. v of assessing a courseware package is to try it out, but its mani. .cional branchings and the way in which these are decided may

not always be spotted even after several runs on a terminal. One needs to be able to read clearly the corresponding instructions (on the listing or in an accompanying document). This will be simplified if the courseware is written in an authoring language or using a system designed to be easily understood. Users can inspect the courseware packages prepared by the various companies as well as some of those designed for specific microcomputers. This can be done through the manufacturers themselves or their agents in the big distribution centres. Courseware packages can also be examined in the clubs which are springing up in increasing numbers to promote computer applications. Periodic exhibitions, and in time probably also permanent exhibitions, i.e. computer museums, are well worth organising since they make it possible for school officials and individual consumers to gain personal knowledge of the advantages and shortcomings of various courseware packages through comparative inspection of many such systems.

e) Courseware Library

117. For products available in the UK, CEDAR has a bibliographic information service (in a databank and available on microfiches), a library, a set of courseware packages that can be examined on the spot and a series of extracts from courseware material on videotape. It has a telephone enquiry service and runs a CAI training centre. Several countries have similar courseware libraries which should make it possible to arrange an exchange of information and demonstration material. Libraries can soon be expected to offer direct remote access to their courseware banks or at least, to those parts from which the level and the main features can be assessed.

Section IX

EVALUATION, ANALYSIS AND REFINEMENT OF COURSEWARE

118. We have already mentioned several journals and periodicals which publish comments on the quality of particular courseware material. There are, in fact, several dozen such periodicals in the United States, as a result of which a publication has recently been launched with the title "Evaluation of Educational Software: A Guide to Guides". Since most of the criticism in these reviews is fairly subjective, this is not an easy way to get an idea of the qualities and shortcomings of a courseware package. However, one periodical which should be mentioned is Educational Technology to which a number of specialists contribute whose comments -- highly critical on occasion -- are published alongside the author's reply. Since the creation of ENTELEK, the first courseware databank (1965), and as the result of a great deal of effort, it is now possible to assess courseware on the basis of criteria which are as comprehensive and objective as possible. The CONDUIT method of assessment is a particularly good example and a number of systems of evaluation have been modelled on it (e.g. the Quebec Department of Education and the Musée de la Villette in France). The tendency nowadays is to concentrate on criteria whereby the quality of the contribution that the microcomputer makes to the educational process may be measured.

119. As school systems grow more concerned with and dependent upon CAI materials, we can expect the scientific content and professionalism of courseware reviewing to increase. Computerised courses in a given subject area can best be reviewed by professionals able to assess the choice and sequencing of topics, accuracy of explanation and simulation, quality of graphics, flexibility of presentation, and ability to deal adequately with the kind of errors and misappreciations typical of students at a given grade level. Informal review by individual experts and expert panels will be supplemented by formal, statistically monitored experiments, in which courseware is brought into trial use by school classes, including both "typical" classes and classes representing various special educational situations, such as disadvantaged, handicapped, or gifted children. Experiments of this type allow detailed information on student interactions with courseware to be collected. For example, one can measure the number of times courseware meets totally unanticipated student responses, students' speed of response to various questions, the frequency with which optional help sequences are requested, student success with frequent short quizzes, etc. The courseware producer is in the favourable position of an author able to observe minute details of reader reaction to his book.

120. Careful external reviewing, experimental use, and systematic collection of student and teacher response to courseware will allow it to be progressively improved and systematically tailored to a variety of educational and national settings. The ethical rules to be observed here are mentioned in paragraph 12 (iv) above. Provided that the overall structure of a computerised course is sound, portions of the course that are frequently judged to be dull or rigid can be made more lively and flexible by the use of additional graphics, video and audio materials, optional bypasses which allow students to advance more rapidly or along different paths through a lesson, etc. Common student responses which are not handled adequately can be systematically classified and their treatment improved by adding additional response-analysis code. Passages which are found to be too difficult can be supplied with additional explanatory text, diagrams, animations, simulations, and optional "HELP" sequences. We anticipate that many courseware classics suitable for broad national and international use will ultimately emerge from this continuing process of refinement.

121. Thanks to the computer, courseware provides a living product that can be systematically refined in the light of the statistical information received. There is therefore a need to ensure the portability of courseware follow-up, i.e. the recording and processing of students' responses and their communication to the author.

Section X

THE COMPUTER AS A TOOL FOR EDUCATIONAL RESEARCH

122. As we have seen, courseware is a living product that successive authors can improve in the light of student response to it. In fact the computer as an educational research tool can provide much wider assistance:

a) Contribution of the Computer to Experiments in Cognitive Psychology

123. The computer's value lies in:

i) Its ability to measure and process a large number of variables;

ii) Its ability to store a vast number of experiments;

iii) Its speed;

iv) Its accessibility which, in particular, makes it possible to repeat an experiment with the same subject or with other subjects.

124. At first sight, the conduct of an experiment should not be disrupted by the computer, which is neutral and objective. The role of cognitive psychology is to study the nature of human mental abilities and the processes that bring them to bear on problems under such conditions. Considerable work has been done in the past to determine intellectual capability to perform certain tasks or to make diagnoses with a view to providing a remedy (as in the case of the handicapped or disadvantaged).

125. Other important work has focused on basic learning processes. The following are some examples of where the computer can make a useful contribution:

i) Experiments involving memorising a series of syllables in relation to the time gap between the terms in the series or between different series;

ii) Monitoring the perception of images on a screen in relation to display time;

iii) Discerning frequency patterns in random samples;

iv) Reflexes conditioned by different stimuli.

b) The Opening of New Fields of Research in Cognitive Psychology

126. The development of computers capable of solving statistical or logical problems has had a considerable impact on cognitive psychology. Speech perception has been studied by means of a computer-controlled speech synthesiser. The results throw new light on difficulties of perception and difficulties in speaking a new language. Progress has been made in understanding the processes involved in reading through the use of screens where the display is computer controlled. The Elementary Perceiver and Memoriser (EPAM) Program has been used to gain insight into the perception of a chess player. In another context, the way young children use the LOGO language has thrown new light on "flashes of inspiration" of certain kinds.

c) The Computer's Contribution to the Theory of Cognitive Psychology

127. The computer, by an analogy which needs to be treated with caution, suggests patterns for explaining the operation of the brain and human behaviour:

-- Coding of information;

-- Organisation of information;

-- Operations on this information;

-- Logic constraints on such operations;

-- Time constraints on such operations.

128. Logical, algorithmic and heuristic patterns are not the only ones to consider. The mind also works intuitively and emotionally. The computer can help to clarify these forms of behaviour. The computer's own disruptive role (at second sight) should also be capable of analysis.

129. It is generally accepted that memory is divided into a short-term memory of limited capacity and a long-term memory. Other models depict the strategies used in understanding a text in natural language, the detection threshold theory for hearing a signal against a background of noise, the representatin of knowledge of a vocabulary and the representation of particular images. New knowledge would seem to be understood in relation to old. In presenting a subject, therefore, the educator must, as far as possible, link up with prior knowledge and organise his material in a manner compatible with what can be stored in the memory.

130. The laws deduced from these models, once they have been verified experimentally, can be expressed in quantitative form or by computerised simulation of behaviour. An attempt is being made to find a simulation which corresponds with experience to explain how a child discovers and applies the rules of grammar. There are other examples of rules defined by computer simulation which concern the difference between a novice and an expert.

d) Artificial Intelligence

131. The object of artificial intelligence is to reproduce thought processes that, because of their complexity or their nature, were regarded as possible only for the human intelligence (e.g. analogies, generalisations, hazy logic, etc.). Any problem, for which there is no known algorithmic solution, a priori belongs in the area of artificial intelligence. Initially, this involved solving puzzles, simulating an average chess player or understanding a natural language restricted by a limited vocabulary. It became clear that the system had to acquire knowledge, establish a process of logic and formulate (and at the same time check) the solutions.

132. Existing expert systems employ logic processes and experience stored in a memory and utilised subsequently as appropriate. They are used for:

-- Understanding natural language;

-- Mechanical translation;

-- Problem solving;

-- Demonstrating phenomena;

-- CAI.

133. The STEAMER Program, for example, teaches students how the steam engine operates. The BUGGY Program simulates the results of additions or subtractions done by a student who systematically makes one of the 70 mistakes revealed by actual observation, e.g. a student who confuses number and figure will misunderstand the instruction "add the numbers" (Ex. 1) or "always subtract the smaller number from the larger" (Ex. 2 and 3):

Ex. 1	Ex. 2	Ex. 3
17	41	328
+5	-7	-56
13	46	332
(1 + 7 = 8, + 5 = 13)	(7 - 1 = 6)	(8 - 6 = 2; 5 - 2 = 3)

Normally it is up to the teacher using this program to spot the error of principle which is being made in front of him. The BUGGY Program, on the other hand, is able to spot the systematic error or a combination of several systematic errors made by the student. The diagnosis is followed by corrective exercises and the teacher is informed of the student's performance and progress. In the words of J.L. Laurière, "The degree of detail of artificial intelligence programs highlights the shortcomings, in every discipline, of conventional types of instruction and brings out things about which, usually nothing is said in education."

e) Educational Research Prompted by the Writing of Courseware

134. It soon becomes apparent to the author, or rather to the team that puts together a courseware package, that they need to go through a process of

thinking that is somewhat in the nature of epistemological and pluridisciplinary research, or a process of rediscovery:

i) Rediscovery of the subject matter to be taught. This has to be approached in a rigorous, accurate and unequivocal manner when preparing courseware. Concepts must be precisely defined, a recognised vocabulary used and there must be no doubt as to the objective to be achieved and tested;

ii) Rediscovery of the way to teach. The vast variety of possible teaching strategies, routes that can be followed and ways of asking questions make it essential to re-assess the advantages and disadvantages of particular procedures;

iii) Rediscovery of the difficulties of learning. Courseware follow-up will reveal the mistakes made by the students and it is then necessary to discover why the mistakes were made and find the right remedies;

iv) Rediscovery of the difficulties of assessing either the student or one's own teaching. This personal educational appraisal by the teacher himself rarely occurs outside the context of CAI. The computer is an instrument of measurement and teachers and students alike must learn how to derive the utmost benefit from it.

Section XI

TRAINING IN THE USE AND PRODUCTION OF COURSEWARE

135. Training in the use and production of courseware depends on how the teacher and student use the product. The teacher may use the one-screen multimedia system as a modern electronic version of the traditional blackboard. The simplest uses already current are:

i) Drawing curves, displaying how they alter in experimental conditions (mathematics, physics, chemistry, biology, sociology, economics, etc.);

ii) Animations, to represent a movement, a view in space, a statistical trend, a sum of series or functions;

iii) Calling up a data bank with class participation;

iv) Courseware adapted to the responses of a whole class.

136. If the teacher has one terminal available for one, two or three students, he can let them work at their own pace without intervening. But he can also intervene by visiting students in succession. If he has a master terminal or mainframe, he can intervene directly in the running of the package from his desk, where he can monitor all the students' progress. In some cases, the teacher divides his class into two parts, working more or less traditionally with one-half while the others come to grips with the terminals. Experience shows that the latter become involved in lively discussions among themselves and with the teacher, whose role often then calls for discretion.

137. The teacher's task is different again if terminals are not in the classroom but at home or in a freely accessible library. If the teacher has a master terminal or mainframe linked (sometimes remotely) to the students' terminal, he is in the same situation as above except that he cannot see the students themselves but only what is displayed on their screens. Telephone (or even visiophone) communication would be conceivable but otherwise, the teacher has to work after the event, analysing how the recorded interactions have proceeded. The system itself can help him to do this, by providing overall results and statistics for the individual student, class or package.

138. On the whole teachers like to be able to easily introduce a few changes, personal or associated with the particular time and place. They

would prefer their role not to be limited to one of mere mediator between student and system. Teachers must be given creative possibilities, without overlooking the risks that an overenthusiastic teacher or small team might go off on a tangent. The training provided should, conversely, neutralise the difficulties inherent in any institutional change in a school.

139. Training in data processing, documentation and telecommunications is of course useful, but here we will concentrate on training in the educational applications of computers and audio-visual communications media, taking as the main headings in this respect their use as a teaching aid, as a technique or as a science depending on the level of training required.

140. The press, radio, television, conferences and exhibitions are creating an awareness among the public of the educational possibilities of electronic games and, by extension, of the multi-media combinations controlled by microprocessor. There is a substantial demand for training in these new educational techniques from teachers and instructors in the teaching profession, in firms of various size and in clubs.

141. The training OBJECTIVES can be graded in several levels, ranging from straightforward initiation to training of researchers in education sciences by means of interactive audio-visual media to enable them to acquire skills in computer techniques, communications, audio-visual aids, teaching methods, etc.

142. The training METHODS can be of various kinds:

-- Self-instruction of a teacher or a group;

-- Guided instruction, i.e. programmed teaching with the aid of a computer;

-- Short-cycle training, i.e. about 100 hours of supervised instruction;

-- Long-cycle training, i.e. about 1 000 hours of supervised instruction.

a) Initiation

143. Initiation is possible by reading one of the dozens of periodicals, the handbooks for microcomputer users or from lectures on television. In some cases, a software package is supplied with the microcomputer so that the novice can see its various capabilities as regards operation, computation, display, etc. and manipulate sample dialogues, games or educational simulations. Workshops, training courses and clubs also assist in this process of initiation by providing demonstrations on inexpensive hardware. There are associations which those interested can join (e.g. ADCIS in the United States which is international in character, RECODIC for French-speaking chemists, etc.).

b) Using Courseware

144. The question is one of knowing how to use courseware as a demonstration tool for the teacher or as a medium for a student/machine dialogue. The main

difficulty is choosing a hardware package from amongst those which are compatible with the system used. Some organisations (CNDP in France, CEDAR in the UK, CONDUIT in the United States, etc.) try to help the teacher by providing an appropriate bibliography or even videotaped extracts of courseware material. A courseware package will, in many cases, be accompanied by a descriptive document describing the teaching aims, level and strategy. Once the choice of courseware has been made, it is then a question of being able to use it properly and understanding, in broad outline, the way in which the system operates -- which is what the student's or teacher's handbook should explain.

145. Some multimedia programs guide the user, as does the "Microprimer" program, designed for primary school teachers in the UK using the BBC microcomputer. The program guides them through the taped audio material, the explanatory literature and the microcomputer software. The user thus learns the rudiments as regards the hardware, programming and possible uses. In a short-cycle training course, the emphasis will be essentially on general knowledge of computers and their applications in modern-day society (including databanks and videotex) and, in particular, on the acquisition of the ability needed to use courseware in education with various types of terminal from slide projector to videodisc.

c) Modifying Simple Courseware

146. Modification may involve anything from simply up-dating the courseware (places, dates, etc.) to constructing a new courseware package based on a well-proven teaching strategy, in which case, it is necessary to know how to interpret and adapt, with the aid of the user's guide, all the instructions written in a computer or authoring language. Often, this knowledge can be self-acquired. Prompt modes are possible in the case of rigidly defined teaching strategies. A short-cycle training course is recommended and is sufficient to reach this level.

d) Production of Simple Courseware

147. Using low-level authoring languages, it is possible to construct teaching dialogues with conditional branching and limited response analysis. The authors can thus concentrate on the teaching problems and receive the appropriate training. In the case of self-instruction, group discussions are, in practice, necessary. Authoring languages will, in most cases, have prompt modes. Various guides, like those distributed by CONDUIT, give advice on the drafting of teaching material including supporting documents. A short-cycle training course should include these teaching techniques and provide some additional knowledge of computers: utilities, procedures, functions, connection of terminals and computers.

e) Production of Standard High-quality Courseware

148. Here we refer to courseware for which the facilities of an audio-visual studio are not necessary. By using the functions of a fairly complete authoring language the courseware can be written without constraints as regards teaching strategies and without problems of programming. In the case

of standard teaching strategies, a prompt mode can be used and avoids the problem of selecting implicit instructions (e.g. allow for blank spaces or not, upper case/lower case, limitations in the loops, etc.).

149. In a short training course, it is not possible to develop the instruction on computers, since the teaching aspect has to take precedence, i.e. definition of the subject matter, how the microcomputer can help, definition of objectives, analysis of tasks, observation of user reactions, pre-test and post-test, choice of teaching strategy, choice of terminal, writing of supporting documents, tests, comprehension of texts, readability of program, student and teacher reaction, etc.

150. A long-cycle training course would be better, covering a full year, and divided into three roughly equal parts:

i) Data processing aspects: structure of computers, peripherals and data transmission, operating systems, knowledge of a number of languages including BASIC and Pascal, structure of data and methods of program design and authoring systems. Standard and specialised applications of computers should also be dealt with, i.e. databanks, text editors, CAD (computer-aided design), CAM (computer-aided manufacturing), CAT (computer-aided translation), etc;

ii) Teaching applications covering the contribution of computers to education, their different applications and the stages of designing, testing and validating courseware material. The education aspect of the training should cover teaching methods and educational psychology, i.e. learning, the cognitive processes, the objectives of education, the characteristics of students, the diagnosis of their errors or inability to understand, the presentation which is most suited to them or which they themselves might prefer. This part of the training should be rounded off by individual or preferably group work with an experienced team;

iii) Career training: work experience in different schools and in documentation and distribution centres in order to provide an insight into the difficulties encountered by teachers using computers in their work. The running of CAI centres or computer clubs in schools will be facilitated by the contacts built up during the course of this work experience. In addition, training needs to be provided on the operation of the hardware and light maintenance.

f) Creation of Original Courseware

151. Some parts cannot be dealt with using an authoring language. This is often the case with simulation, learning games or artificial intelligence where a special module has to be written in a computer language. The author or authors must be thoroughly familiar with all of the above aspects and be able to manipulate the graphic and animation capabilities of the computer. At this stage, it becomes useful to know something about the concepts of artificial intelligence. The level of training has to be equivalent to that

of research. It is available in universities and institutes at undergraduate level culminating in a degree in computer science, telecommunications or education.

g) Production of Complex Courseware

152. By this is meant courseware such as that used for training pilots for which substantial audio-visual facilities are required, i.e. television studios, videodisc, etc (see Ancient History Scenario, Section I, para. 11).

153. The facilities required are something like those needed for making a film or television programme. Training in these audio-visual techniques needs to include studying the different situations where the computer linkup offers new scope, e.g. audio-visual databanks, videodisc operation, computer-aided design, computer animation, etc.

Annexe 1

ACRONYMS

CAI	Computer Assisted (Aided)	Instruction	Equivalents in French
CAL	" " "	Learning	
CAT	" " "	Teaching	
CBE	Computer Based	Education	EAO Enseignement Assisté par Ordinateurs
CBL	" "	Learning	
CBT	" "	Training	
CMI	" "	Instruction	
MCQ	Multiple Choice Question		QCM : Question à Choix Multiple
MCR	Multiple Choice Response		

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Annex 2

BASIC GLOSSARY

I. COMPUTER TERMINOLOGY

COMPATIBILITY (Compatibilité):
Feature of any hardware or software that a computer system can work with.

COMPUTER GRAPHICS (Graphique):
Using a computer to generate and display graphics. Several curves can be displayed simultaneously and a variety of colours (or shades of grey) can be used.

COMPUTER LANGUAGE (Langage):
Language in which a programmer or user instructs the computer.

DISKETTE, FLOPPY DISK (Disquette):
A flexible magnetic disk of smaller size and capacity.

EDITOR (Editeur):
Software tool helping to produce other software. For example:

-- Databank;
-- Character set;
-- Screen;
-- Graphics;
-- Text editors.

HARDWARE (Matériel):
Set of physical components used to process information.

MAGNETIC DISK (Disque magnétique):
A magnetically coated disk on which data are recorded.

MENU (Menu)
List of options or facilities to be chosen for instructing a computer. A menu is usually displayed on the VDU with a selector symbol for the user to position on the screen. A CAI can have a large number of menus.

PERIPHERAL (Périphérique):
A device connected to the central computer for data entry, storage or output: e.g. a printer, VDU, mass storage.

SOFTWARE (Logiciel):
Set of programs, processes and rules, possibly with documentation, relating to the operation of an information processing system.

TERMINAL (Terminal):
Device for remote access to a computer system.

TRANSPORTABILITY (Portabilité):
The ability of a program to run on different types of computer system.

VIDEODISC (Vidéodisque):
A process for the storage of animated sequences and fixed images and for their reproduction on a home television screen.

VIEWDATA, VIDEOTEX, (Vidéotex):
A system enabling a home television screen to call up pages of alphanumeric and graphic information via the telephone network. The user can send messages back and thus interact with the computer.

VISUAL DISPLAY UNIT, DISPLAY DEVICE/TUBE, VDU (Visu):
Equipment for the visual, temporary display of information.

II. CAI TERMINOLOGY

AUTHORING LANGUAGE (Langage auteur):
A computer language more or less closely related to a natural language with which an author can instruct the CAI system.

CAI (CBL, CBT SYSTEM) (Système EAO):
Combination of hardware and software resources with which to create, modify, execute and disseminate courseware. Software resources are usually distinguished between those intended for authors, those for teachers and those for learners. The following parts are often distinguished:

-- Administrative (administration);
-- Authoring (auteur);
-- Presentation (présentation).

COMPUTER ASSISTED INSTRUCTION (CAI, CBL, CBT)
(Enseignement assisté par ordinateur, EAO):
Interactive use of the computer as an educational tool at the centre of an educational relationship between learners and teachers. Broadly, this involves two dovetailing parts: the education part (CAI, CAL), the presentation of interactions, analysis of responses, comments, etc.; and the management part (CMI) initiating the student, branching, educational follow-up. Some English-speaking writers refer to all of these as computer based learning (CBL) or computer based training (CBT).

COURSEWARE (Didacticiel):
A complete educational package for use on a CAI system to achieve an overall educational goal.

COURSEWARE EDITOR (Editeur de didacticiel):
Software tool enabling the courseware author to concentrate on the educational goal and concern himself as little as possible with the computer side. Examples (in addition to the ordinary editors) are those for:

-- Dialogue;
-- Educational situations;
-- Scenes;
-- Prompt/queues;
-- Response analysis;
-- Response assessment;
-- Decision unit;
-- Environment;
-- Courseware.

RESPONSE ANALYSIS (Analyse de réponse):
Testing for a match between a learner's answer and the answers expected by the author. Each form of response expected, such as a numerical or textual response or an answer to a multiple-choice question, has its own analytical process.

Annex 3

ADDITIONAL GLOSSARY

I. COMPUTER TERMS

ALGORITHM (Algorithme):
A set of instructions precisely indicating the order in which a combination of operations must be performed to obtain solutions to all problems of a given type. The number of operations described and the number of operations implemented must be finite.

CHARACTER SET (Police de caractère):
Set of character shapes and sizes available for display on screen, or output on printer.

CONVERSATIONAL MODE (Mode dialogue):
Data processing mode in which the users can interact with the system.

DIGITAL, NUMERICAL, NUMERIC (Numérique):
Representation of data, physical magnitudes by means of characters, usually figures, rather than by electronic analogy and hence, any system, device or process for data when represented digitally.

EXPERT SYSTEM (Système-expert):
A system simulating the reasoning procedures of a human expert. The computer is given general rules (strict or approximate) enabling the program running them to draw conclusions, perhaps in terms of probabilities, from data introduced.

INFOGRAPHY (Infographie):
Application of computers to graphic presentation and picture processing.

INFORMATION TECHNOLOGY, "TELEMATICS" (Télématique):
Refers to all techniques and services involving both computers and telecommunications.

INTERACTIVE (Interactif):
Describes hardware, software or operating conditions in which the user can interact with the system in real-time conversational mode.

JOYSTICK (Manche à balai):
Moveable device for pointing on the screen.

LIGHT PEN (Photostyle):
Input device which the operator can point directly at a VDU screen.

MICROPROCESSOR (Microprocesseur):
Miniaturised processor all of whose components are in principle combined in a single integrated circuit.

MIPS (MIPS):
Million instructions per second (for data transmission speed).

MOUSE (Souris):
Device whose movement over a surface controls a VDU cursor (as a joystick does).

OPERATING SYSTEM, OS (Système d'exploitation):
The software which manages a computer. It is independent of the application programs but essential for running them.

PIXEL (Pixel):
Smallest picture element on a VDU screen. The whole screen area consists of rows and columns of pixels. The number of pixels determines graphic detail quality.

PROCESSOR (Processeur):
Part of a computer or other machine which interprets and executes instructions. By analogy, set of programs allowing the computer to implement programs written in a particular language.

PROM CARTRIDGES (Cartouches prom):
Software in the form of a plug-in module. Programmable read-only memory (PROM) (mémoire morte programmable).

RANDOM ACCESS MEMORY, RAM (A accès aléatoire, mémoire vive):
Memory which need not be accessed sequentially and whose content can be altered in ordinary use.

READ ONLY MEMORY, ROM (Mémoire morte)
Memory whose content cannot be altered in normal use.

STORAGE, MEMORY (Mémoire):
Device for recording, storing and recovering data.

SOFTWARE PACKAGE (Progiciel):
Complete, documented set of programs designed to be supplied to more than one user for a given application.

TOUCH SENSITIVE (Tactile):
Refers to a screen which can recognise that part of its area has been touched for input purposes.

UTILITIES (Utilitaires):
Programs available to the operating system so that the programmer need not keep writing outlines of instructions for frequently recurring tasks.

II. CAI TERMS

BRANCHING (Branchement):
Number of routes through which the student may be guided after replying to a question or prompt. The branch can in principle be selected according to the student's most recent answer, together with earlier answers, the teacher's decision or the choice of the student himself.

CAPABILITY (Fonctionnalité):
Analysed from a capability point of view by teachers, a CAI system includes basic educational capabilities essential for the development and use of the courseware. These are "capabilities" common to any CAI system defined independently of any implementation.

CANONICAL FORM (Forme canonique):
For every form of answer expected there may correspond a "canonical form" in which the answers expected by the author are expressed and into which the learner's answers are also transformed before analysis.

DECISION UNIT (Unité de décision):
A decision unit designates, after a calculation involving the dialogue environment in particular, the sequence of actions to be performed (e.g. the next interaction unit).

ENVIRONMENT (Environnement):
Set of information accessible at any moment for interaction and educational follow-up. The system either updates it automatically or on request by the author while using the system. The information allows for follow-up of lessonware, courseware and students.

A distinction is made between:

-- Lessonware environment;
-- Courseware environment;
-- Pupil environment.

FOLLOW-UP (Suivi):
Set of information describing the results of using a courseware package. The information is classified according to dialogue, courseware and pupil environments.

IMPLICITS (Implicites):
Instructions implicitly assumed throughout a courseware package but contained in the set of programs guiding the computer. Implicits may be systematic for a given system, or may be defined by the author. For example:

-- Ignore blanks, incorrect use of upper case/lower case, spelling errors;

-- Restrict the coupling factor to the value of three, lower the level of questions asked after two successive mistakes;

-- Accept authorised requests.

INTERACTION UNIT (Unité d'interaction):
Combination of actions corresponding to a learner/system interaction, on the initiative of the author:

-- Output author information;

-- Output question or prompt

-- Take in learner messages;

-- Discriminate between answer and request;

-- Reduce to canonical form;

-- Analyse answer;

-- Output comment reflecting the result of the analysis.

LESSONWARE (Dialogue):
Smallest coherent pedagogical unit that can be presented to the learner with a view to achieving one specific teaching goal. Interaction is an indivisible subject of a courseware package. Lessonware is an indivisible subset of courseware. It is self-standing and can be used in different contexts and different courseware packages by a teacher who need not necessarily have written it himself. Lessonware can include components which the teacher using it can modify.

LINK UNIT (Unité de liaison):
A link unit is associated with the dialogue and describes the condition for moving on to other dialogues according to the courseware and pupil environments.

LOOPING FACTOR (Facteur de bouclage):
When the student does not give the expected answer, the maximum number of times the question is asked in the same form.

PEDAGOGICAL OBJECT (Objet pédagogique)
The word "object" can designate an item of information as well as an action. A pedagogical object is of direct interest to the teacher. Examples of objects are: a message intended for the learner, the action of sending such a message.

PEDAGOGICAL SITUATION (Situation pédagogique)
Combination of activities permitting an exchange with the learner and the move on to the next pedagogical situation. For example, the combination of one unit of interaction and one associated decision unit.

PROMPT/CUE (Sollicitation):
Expectation of some action on the part of the learner. For example, after asking a question, a reply is prompted: the system stands by until the learner uses the resources at his disposal to formulate his reply; the learner can also make a request.

REQUEST (Requête)
Introduced on the initiative of the learner, a request calls up resources outside the current interaction, e.g. for consulting a dictionary, performing a calculation.

SCENE (Scène)
Organised set of elementary informative messages intended for the learner. A scene deploys different sources of information: visual, sound, audio-visual, etc.